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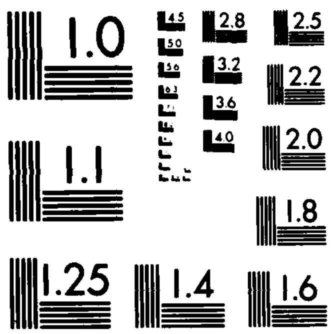
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NATIONAL COMMUNICATIONS SYSTEM

TECHNICAL INFORMATION BULLETIN
83-4

STUDY OF POTENTIAL STANDARDIZATION OF VIDEO TELECONFERENCING SYSTEMS
VOLUME 1-FINAL REPORT

MAY 1983

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VIDEO TELECONFERENCING
MOTION CODECS
DIGITAL TELEVISION

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

SEVERAL DIFFERENT FULL-MOTION TV TELECONFERENCING SYSTEMS USING NON-COMPATIBLE MOTION CODECS HAVE BEEN IMPLEMENTED. THESE VIDEO TELECONFERENCING SYSTEMS OPERATE AT VARIOUS DATA RATES WITH VARYING DEGREES OF PERFORMANCE. IN ORDER TO PROVIDE FOR THE COMPATIBILITY AND INTEROPERABILITY AMONG VIDEO TELECONFERENCING SYSTEMS, THE STUDY WAS INITIATED BY THE NATIONAL COMMUNICATIONS SYSTEM TO COMPARE EXISTING MOTION CODECS TO DETERMINE THE FEASIBILITY OF ESTABLISHING FEDERAL STANDARDS. THE OBJECTIVE WAS TO IDENTIFY THOSE

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PARAMETERS WHICH WOULD REQUIRE STANDARDIZATION IN ORDER TO ACHIEVE INTEROPERABILITY IN FULL-MOTION VIDEO TELECONFERENCING SYSTEMS.

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STUDY OF POTENTIAL STANDARDIZATION OF

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VOLUME 1 - FINAL REPORT

MAY 1983

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FOREWORD

Among the responsibilities assigned to the Office of the Manager, National Communications System, is the management of the Federal Telecommunication Standards Program. Under this program, the NCS, with the assistance of the Federal Telecommunication Standards Committee identifies, develops, and coordinates proposed Federal Standards which either contribute to the interoperability of functionally similar Federal telecommunication systems or to the achievement of a compatible and efficient interface between computer and telecommunication systems. In developing and coordinating these standards, a considerable amount of effort is expended in initiating and pursuing joint standards development efforts with appropriate technical committees of the Electronic Industries Association, the American National Standards institute, the International Organization for Standardization, and the International Telegraph and Telephone Consultative Committee of the International Telecommunication Union. This Technical Information Bulletin presents an overview of an effort which is contributing to the development of compatible Federal, national, and international standards in the area of digital video teleconferencing systems. It has been prepared to inform interested Federal activities of the progress of these efforts. Any comments, inputs or statements of requirements which could assist in the advancement of this work, are welcome and should be addressed to:

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TSI 83-16

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STUDY OF POTENTIAL STANDARDIZATION OF VIDEO TELECONFERENCING SYSTEMS

- FINAL REPORT -

May 1983

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ARLINGTON, VA 22204

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D E L T A I N F O R M A T I O N S Y S T E M S, I N C.
310 Cottman Street
Jenkintown, Pa. 19046

This report summarizes the work performed by Delta Information Systems, Inc., Jenkintown, PA. for the Office of Technology and Standards, National Communications System, Arlington, VA. under Contract DCA100-82-C-0061, entitled "Study of Potential Standardization of Digital Video Teleconferencing Systems". The contract monitor for the NCS was Mr. Dennis Bodson. The principal investigator for Delta Information Systems was Mr. Robert V. Cotton. Mr. Richard A. Schaphorst also participated in the study effort.

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1.0 Introduction

The National Communications System (NCS), Arlington, VA, contracted with Delta Information Systems (DIS), Jenkintown, Pa., to perform a study entitled "Study of Potential Standardization of Digital Video Teleconferencing Systems" under Contract No. DCA100-82-C-0061. The effort was initiated in July 1982 and concluded in March 1983. This Final Report summarizes the work performed on the study.

1.1 Definition of the Study

1.1.1 Purpose

The purpose of the contract was to study the feasibility of establishing Federal standards for digital motion codecs for use in video teleconferencing systems.

1.1.2 Objective

The objective of the study was to identify and quantify where feasible those parameters which require standardization in order to achieve interoperability and compatibility in digital motion video transmission for teleconferencing systems.

1.1.3 Methodology

The methodology employed in the study included the following key elements.

1. Survey industry to determine who manufactures motion codecs.

2. Solicit vendor codec information, study, and analyze motion codecs.
3. Compare key codec characteristics and parameters.
4. Investigate existing digital motion TV systems.
5. Determine and study communication channels currently being used for transmission of digital motion television.
6. Coordinate with government and other agencies concerned with standardization and interoperability.

1.1.4 Scope of the Study

The scope of this study involves the solicitation of information provided voluntarily from codec vendors, current and future users of digital motion video teleconferencing systems, and carriers supplying teleconferencing services. Additionally, information available in the public domain was utilized.

The scope did not include the testing of motion codecs or motion teleconferencing systems. Further, the establishment of standards for the parameters of a motion codec was not part of the scope of this initial study.

Future efforts necessary to establish proposed standards for motion codecs are discussed in Section 8.0 of this Final Report.

1.1.5 Limitations of the Final Report

Several limitations were imposed upon the study due to time and funding. It is important to understand these factors in reading and accessing the Final Report.

1. The effort was strictly limited to studying only motion digital TV codecs even though there are usually many other systems used in a motion teleconferencing system such as facsimile, audio, and computer graphics. Thus, the motion codecs were analyzed for their ability to stand alone.

2. Although digital audio codecs are included either as a standard or optional capability in most motion codecs, the audio codec performance is not analyzed or compared in this report.

3. All data used in the various comparison tables and figures were furnished by each codec vendor. DIS neither agrees or disagrees with these data but presents the data in the formats for comparison purposes. However, conclusions and recommendations are made in some of the codec performance and specification parameters.

1.2 Types of Digital Video Teleconferencing

There are in general two types of digital video teleconferencing codecs and systems in use today. The first type of digital video codec involves the transmission of only a single frame or single image of television picture. Usually, in this type of video conferencing, sometimes known as freeze frame, still frame, or slow scan TV, one of the 30 TV frames per second generated by the TV camera is "frozen" or "stored" in a digital memory in 1/30 second.

The stored image can be processed or compressed to reduce transmission time and then transmitted over various narrowband data or telephone circuits. It is apparent then that "motion" can not be conveyed with a still frame video codec since a single frame is transmitted rather than a sequence of frames which are necessary to depict motion information.

The second type of digital video codec involves the transmission of real time sequences of TV frames or images in a manner which conveys motion. In some motion codecs, the third dimension of time is utilized in conjunction with the other intra-frame dimensions of television signals for processsing and compressing the image sequences to minimize transmission data rates. The motion codec process is discussed in more detail in Section 3.0 of this report. Still frame digital codecs are not analyzed in the report.

1.3 Overview of Motion Codec Technology

Digital motion codecs have been in operational use for transmitting color TV pictures since 1967 for the Department of Defense. Experimental codecs and systems were demonstrated earlier in 1964 and 1965 for the U.S. Navy and Army. The following subsections provide a brief overview of the history of motion codecs demonstrated or used in operational digital teleconferencing systems.

1.3.1 Codec Equipments

Digital codecs for transmitting video monochrome and color television pictures were developed by various organizations including Bell Laboratories, Philco-Ford, Ball Brothers, and RCA during the 1960's. These codecs operated at bit rates ranging from 108 MBS for PCM coding of color TV to 30 MBS for Delta Modulation coding of monochrome TV. Other coding techniques were also employed with varying degrees of success.

For nearly 10 years no new motion codecs were used operationally in teleconferencing systems primarily due to the high cost of the codec and the relative high cost of the digital communication channel needed to transmit the digital bit stream. Considerable development by vendors was on-going and enhanced codecs using adaptive and interframe coding techniques were developed by American Electronic Labs, Digital Communications Corporation, Comsat Corporation, Nippon Electric Company, and others.

With the advent of satellite digital communications and the reduction in cost of motion codecs, several vendors have recently developed codecs for teleconferencing applications at bit rates ranging from 1.5 MBS to 20.0 MBS. Among the vendors are Compression Labs, Incorporated, Nippon Electric Company, GE-McMichael Ltd., MACOM-DCC, and American Telephone and Telegraph Company. Other vendors such as Widergren Communications have developed codecs to operate at bit rates significantly lower than 1.5 MBS with some additional performance degradation.

It is expected that near-future codecs will be developed to yield performance and quality equilvalent to todays 1.5 MBS codecs but operating at perhaps ½ and ¼ of the 1.5 MBS rate.

1.3.2 Teleconferencing Systems

As mentioned previously, digital motion TV systems were initially installed or demonstrated for evaluation by DOD agencies. In 1964 the U.S. Navy operated an experimental secure TV link which transmitted monochrome TV pictures at 30 MBS with a codec manufactured by Ball Brothers.

In 1965 Philco-Ford demonstrated perhaps the first interframe compression codec for transmitting color TV at 16 MBS utilizing an RCA modem over the NBC analog television network in a program for the U.S. Army.

The first operational secure digital color codec developed by Philco-Ford utilizing DPCM intraframe coding was installed in a Western Union digital microwave system operating at 36.8 MBS for the Department of Defense in 1967. These particular codecs and system are still in operation today. Eleven years later DOD contracted with AEL to deliver two additional codecs employing an improved adaptive DPCM compression algorithm for another secure operational color teleconferencing system which is still in operation.

In the past five years other codecs have been developed and operated experimentally in systems whose bit rates range from 20 MBS to 1.5 MBS using equipments manufactured by NEC, DCC, AND CLI.

The past 1½ years has seen the installation of 1.5/3.0 MBS codecs in several digital motion teleconferencing operational systems using primarily a satellite data link. Among the organizations using or providing motion teleconferencing services are Allstate Insurance, Aetna Insurance, Arco, SBS, ATT, ISACOMM, NASA, Citicorp, and American General Insurance. This list is growing rather rapidly. There are only two codecs, manufactured by CLI and NEC, employed in the above systems. Since the two codecs utilize different compresison algorithms, there is no interoperability or compatibility among motion teleconferencing systems using different vendor codecs.

1.4 Summary of the Report

Section 2.0 provides a brief outline of some current efforts in the standardization process for digital TV technology. A brief technical background of digital TV coding, TV signals, compression techniques and kinds of digital teleconferencing systems based on performance and bit rate is contained in Section 3.0. A description of vendor and market analysis of motion codecs and teleconferencing systems is presented in Section 4.0

The comparison of the motion codecs is provided in Section 5.0 for various codec parameter and performance criteria including resolution, TV test signals, variable motion conditions, data formats and bit error rate performance. Section 6.0 contains a brief description of the communication links being used for digital motion teleconferencing.

In Section 7.0 key parameters are identified for consideratio in the possible development of motion codec standards. Section 8.0 delineates many steps and processes which may be required in order to develop a standard which provides for interoperability of motion codecs. Finally, a number of references and appendices are provided for further in-depth consideration of motion codecs.

2.0 Digital TV Standardization Efforts

This section provides a brief outline of some of the efforts being expended by several standards organizations in the study and development of standards for digital television systems and equipments. It appears that most of the effort is related to the implementation of the digital TV studio of the future. Some of the efforts involve the conversion of color analog TV signals to digital format, decoding of composite color signals into components, control of digital TV equipments, distribution of digital TV signals within the studio, and digital video tape recorders. Nearly all efforts are aimed at the generation, processing, and transmission of broadcast or professional quality television.

No formal standards are known to have been adopted expressively for application to video teleconferencing systems and codecs which operate in the 500 KBS to 6.0 MBS digital transmission rate. These highly compressed digital TV signals generally exhibit preformance which is degraded somewhat from the professional quality achieved at much higher digital transmission rates such as 45 MBS. Perhaps, one reason for this lack of standardization efforts in video teleconferencing systems/equipments is that the technology needed to support and develop low bit rate equipments with acceptable performance is still rapidly growing while cost effective satellite communications needed for video teleconferencing has just recently become readily available. The CCITT (Study Group XV) is now studying several recommendations aimed at video teleconferencing systems.

This study represents one of the initial attempts to begin the standardization process for motion codecs for video teleconferencing. The following subsections provide insight into some of the activities of standards organizations in the areas of digital TV.

2.1 International Radio Consulting Committee (CCIR)

The CCIR is an international standards organization which develops standards relating to international television communications. CCIR has just recently adopted Recommendation AA-11 which defines standards for the component coding of television signals. The standard is commonly known as the 4.2.2 sampling hierarchy because the luminance signal (Y) is sampled at twice the frequency of the two color difference signals (R-Y, B-Y). In the standard adopted, the luminance signal is sampled at 13.5 MHZ and the chrominance signals at 6.75 MHZ.

An important feature of the standard is that there are the same number of pixels (samples) per digital active TV line for both 525 line and 625 line television systems (720 for luminance and 360 for chrominance).

One of the current CCIR activities is addressing specifications for a digital control protocol to be used in the digital TV studio.

2.2 Society of Motion Picture and Television Engineers (SMPTE)

SMPTE is perhaps the most active standards organization working on Digital Television standards in the United States. Its working group on Digital Video Standards in coordination with other international groups helped to develop the component digital coding standard described above. Some of its current efforts as reported by SMPTE are listed below.

1. Television Video Committee

   A subgroup is working to develop a standard for the digital control of TV equipments.

2. Video Recording and Reproduction Technology Committee

   A working group is developing standards for component analog video 525/60 TV signals which is to be coordinated with other digital video standards.

3. New Technology Committee

   The Digital Video Standards working group is developing a digital studio interface. The Digital Television study group is addressing the problems of common carrier transmission in the mixed analog/digital environment and also studying the different digital hierarchical transmission rates in different regions of the world. A subgroup on Digital Studio Implementation is studying the transition from analog equipment to component - coded digital equipment in television productior post-production, and broadcasting.

Another study group on Digital Television Tape Recording is investigating the preferred characteristics of a digital videotape recorder.

A study group on High Definition Television is working toward a single world-wide standard for a HDTV system.

2.3 International Telegraph and Telephone Consultative Committee (CCITT)

Study Group XV and its working party on visual telephony is considering several draft recommendations pertaining to digital video teleconferencing. A draft recommendation on a frame structure for digital transmission of video conference signals at 2048 KBS has been approved by the study group.

A preliminary draft for a codec standard at 2048 KBS has been adopted as a framework for a future recommendation. Other submitted contributions being studied involve the AT&T Picturephone Meeting Service and the British Telecom UK Video-conferencing Services Trial. Shortly a contribution to be studied involves Video Teleconferencing Transmission at 1544 KBS.

Another area to be studied is digital transcoding (conversion of bit rates and coding laws) and TV standards conversion methods.

2.4 Joint Committee on Intersociety Coordination (JCIC)

This organization was formed in the 1950's to coordinate television standards activities. The current members of the JCIC are the following organizations.

SMPTE- Society of Motion Picture Television Engineers

EIA - Electronic Industries Association

IEEE- Institute of Electrical Electronics Engineers

NAB- National Association of Broadcasters

NCTA- National Cable Television Association

Current efforts involve coordinating activity toward the standardization of advanced television systems. Digital TV standardization efforts are also coordinated within the JCIC.

2.5 European Broadcasting Union (EBU)

The EBU has previously functioned in the areas of television technology for the European PAL and SECAM television systems. Recently, the EBU is participating in international task forces and joint steering committees to address compatible world-wide specifications in the emerging digital technology.

2.6 Institute of Television Engineers of Japan (ITEJ)

The ITEJ has formed a new group called the Ad Hoc Committee on Digital Television. The committee is investigating technological possibilities of digital television, collating information from the television broadcasting industry and transmission companies, and contributing to the various standardization efforts on digital TV.

2.7 Other Standards Organizations

There are several other organizations which are involved in developing, participating, and promulgating television and digital TV specifications and standards. Details of their current efforts in digital TV are not known at this time. The following is a partial listing.

ISO- International Organization for Standardization

ANSI- American National Standards Institute

IEC- International Electrotechnical Commission

IEU - International Engineering Forum

Section 2.0 References

2.1 "Engineering Report", Roland J. Zavada, SMPTE Journal, April 1983.

2.2 "SMPTE Agrees on Worldwide Digital Standard", Bob Paulson, Broadcast Management Engineering, January 1982.

2.3 "Videotape Recording: Digital Component Versus Digital Composite Recording", E. Fraser Morrison, SMPTE Journal, September 1982.

2.4 "Working Group on Digital Video Standards: The Current Position on the Studio Digital Video Interface," Ken P. Davies, SMPTE Journal, September 1982.

3.0 Technical Background

The purpose of Section 3.0 is to present the technical background for the subject study of full motion TV codecs. This background discussion is divided into two elements listed below and discussed in the following sections:

1. The Overall Teleconferencing Environment
2. Discussion of Full Motion TV Codecs

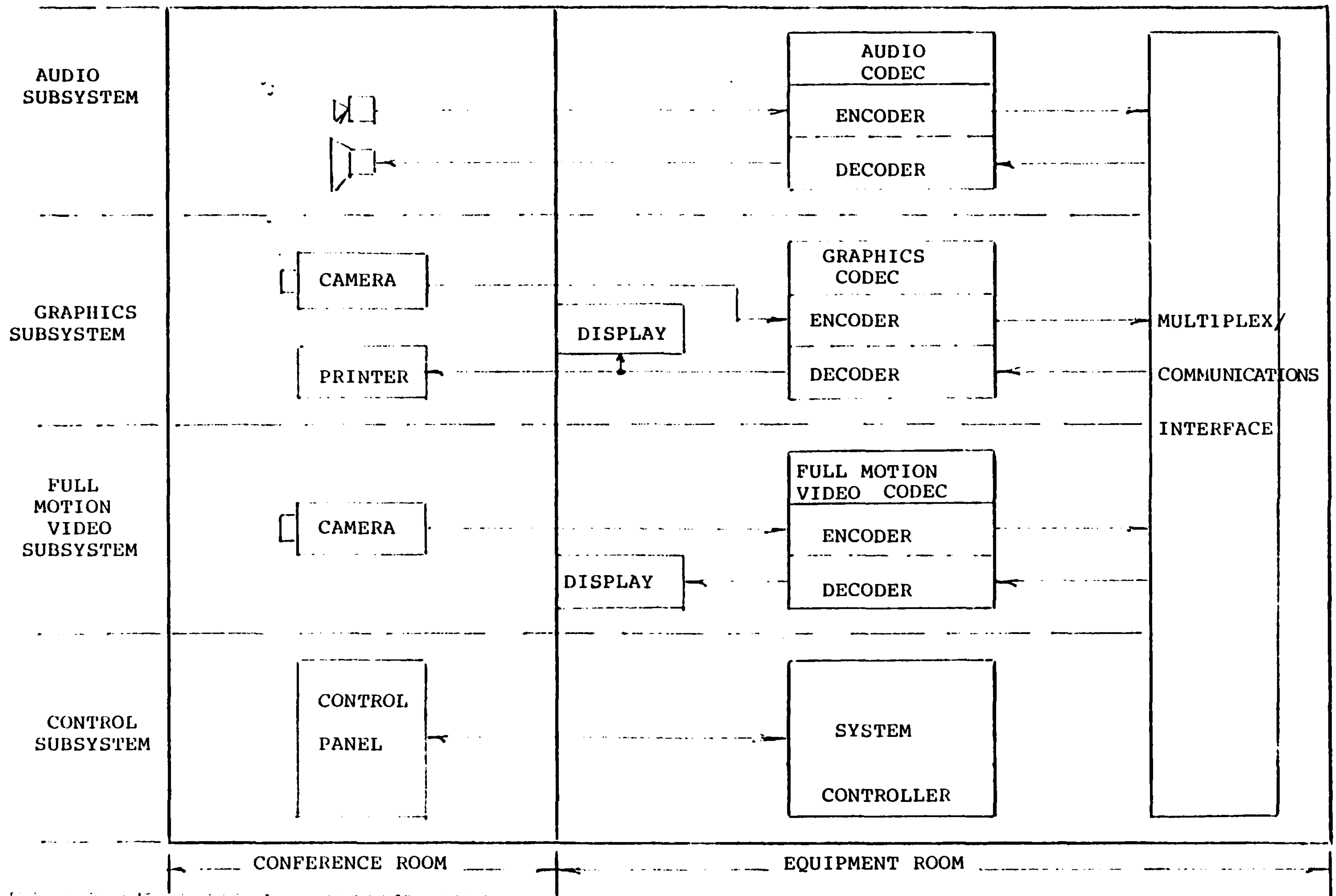
3.1 The Overall Teleconferencing Environment

Figure 3.1 is a functional block diagram of a generic teleconferencing system. Any teleconferencing system must provide an audio communication capability. Although the diagram is drawn to indicate the audio is digitized prior to transmission, this is not always the case. There are many teleconferencing systems which employ analog audio transmission. As an added complication an echo canceler will be required if there is an open microphone and the signal is transmitted by satellite.

If one desires to supplement the audio capability with visual communications the first level of visual enhancement would be to transmit still frame graphics as opposed to full motion video. The use of graphics is particularly advantageous in a problem solving application at lower organizational levels. In a situation of this type it is usually desirable to transmit documents such as

FIGURE 3.1.1

FUNCTIONAL BLOCK DIAGRAM OF A GENERIC TELECONFERENCING SYSTEM



a typed page, briefing charts, sketches, schedules, etc , but full motion video is frequently not required.

The graphics subsystem can take on two different types of configuration - (1) video or (2) high resolution facsimile. The video graphics system has the disadvantage of low resolution (480 visible scan lines/ frame) but the advantage of color. The high resolution system has the advantage of 2200 scan lines/frame to make an 8½ x 11 page readable but the disadvantage of reproducing the page in black and white only. In either case transmission is digital, and a codec is required to interface the camera/display with the digital communication subsystem.

The full motion video system is desirable for use at high organizational levels where it is important to create the natural environment of a teleconference room. In some teleconferencing cases the analog video signals to/from the camera/display are directly transmitted over an analog transmission channel. However the communication cost for a long haul video channel is very high. For this reason most full motion video systems employ a codec which reduce the transmission bit rate to the T-1 rate of 1.5×10^6 bits/sec. The cost of a T-1 channel is much less than the cost of a full analog video channel. The subject study is concerned with the potential standardization of these full motion video codecs.

The signals to/from the audio, graphic, and full motion video codecs are fed to a communication subsystem for transmission. Several vendors have developed multiplex equipment which integrate the audio, graphics, and full motion signals into a single bit stream for transmission.

Figure 3.1.1 also shows a control subsystem which is used by the operator to control the teleconference. The control panel in the conference room has been configured two different ways. In one case a custom set of control elements are "hard wired" to the system controller. In another case the control panel is a touch screen CRT where the controls are displayed on the CRT and the operator activates the control by touching the CRT screen.

This report is concerned primarily with the standardization of parameters for the full motion video codec. However, economics have dictated that the functions of the other three subsystems - audio, graphics, control - are usually integrated into the full motion video codec. For this reason the standardization process may require becoming involved with the audio and graphics subsystems as well as the full motion video.

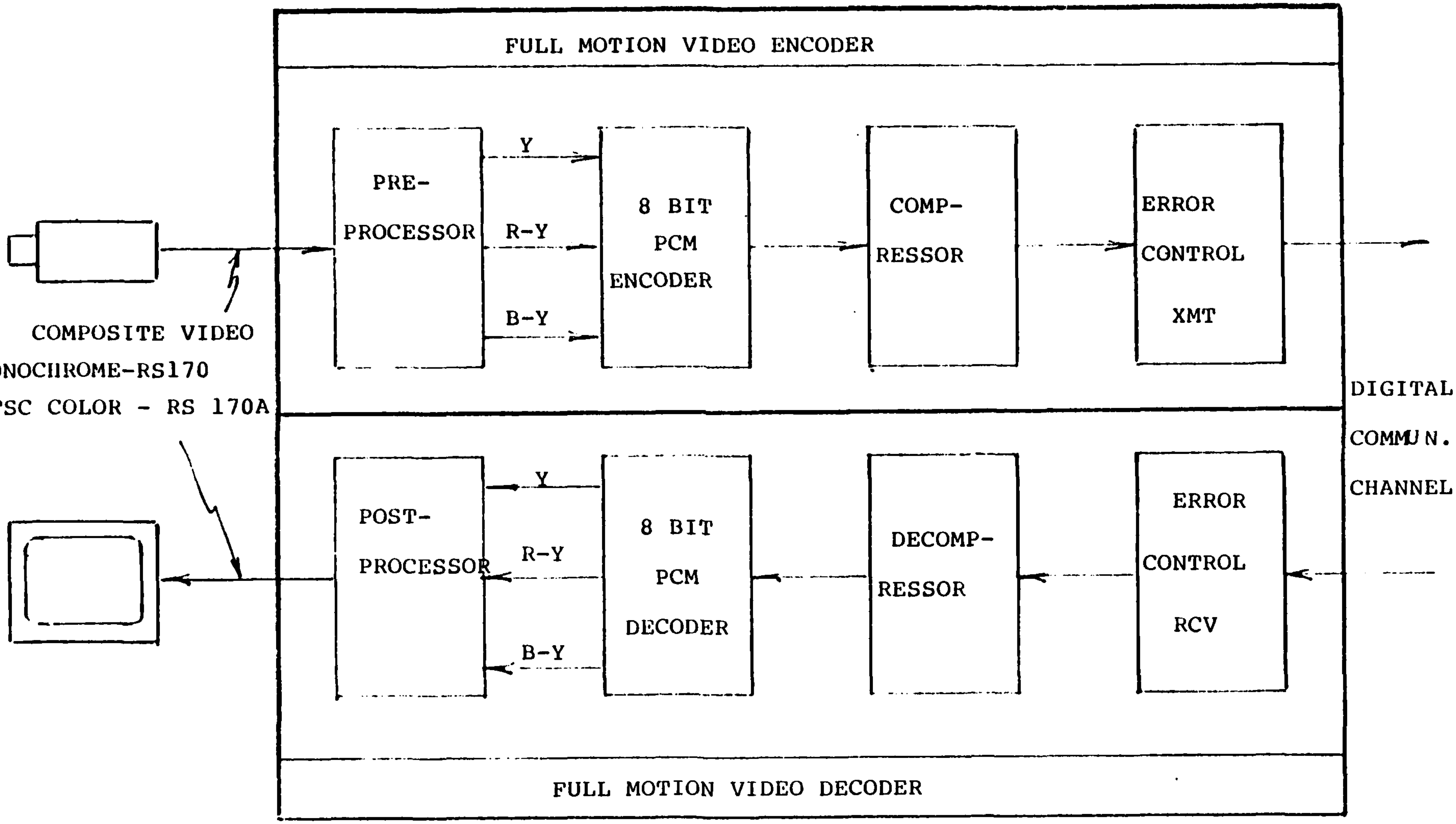
3.2 Discussion of Full Motion Video Codecs

3.2.1 Overview

Any CODEC has two parts: an enCODer which converts an analog signal to digital form, and a DECoder which reconverts the digital signal back to the original analog format. A full motion video codec is one which encodes and decodes the standard video signal (RS170 or RS170A - see Section 5.4) with the intent of reproducing the motion characteristics of the original scene. This is to be contrasted with the Freeze Frame Video Codec which encodes/decodes the same standard video signal but makes no attempt to reproduce motion in the scene. It merely freezes or snaps one TV frame from the input signal and transmits this over a narrowband channel.

Figure 3.2.1 is a functional block diagram of a generic full motion video codec designed to process the NTSC color signal. Most systems first process the video signal by dividing it into three spectral components - luminance (Y) and two chrominance components. Usually the two chroma signals are R-Y and B-Y which have an equal handwidth. In some case the color signals are I and Q which are allocated different handwidths. There are some codecs which do not first divide the video signal into components; instead they directly digitize the composite input video signal. This, however, is not commonly done.

FIGURE 3.2.1 FUNCTIONAL BLOCK DIAGRAM OF A GENERIC FULL MOTION VIDEO CODEC



Referring to Figure 3.2.1 the 3 component video signals are next digitized by an 8 bit PCM coding process. The sampling rate of the A-to-D converter can vary greatly. In the case of commercial broadcast studio equipment the sampling rate of the luminance signal is 13 x 10^6 samples/sec. In other codec systems which transmit the digital at 1.5 mbps representative sampling rates are shown below.

Table 3.2.1 Representative Codec Sampling Rates

Component	Sampling Rate (MHZ)	Bits/ Sample	Bit Rate MBS
Luminance	7.2	8	57.6
R-Y	1.5	8	12.0
B-Y	1.5	8	12.0
		Total	81.6

The above table shows that the 8-bit coding process typically results in a composite bit rate of over 80 x 10^6 bits/sec being fed to the compressor. Since the usual transmission bit rate for the teleconferencing application is 1.5 x 10^6 bps the compressor must typically compress the signal by over 50 to 1. This is no easy task. Indeed the compressor/decompressor is quite complex, dominating the overall structure of the codec.

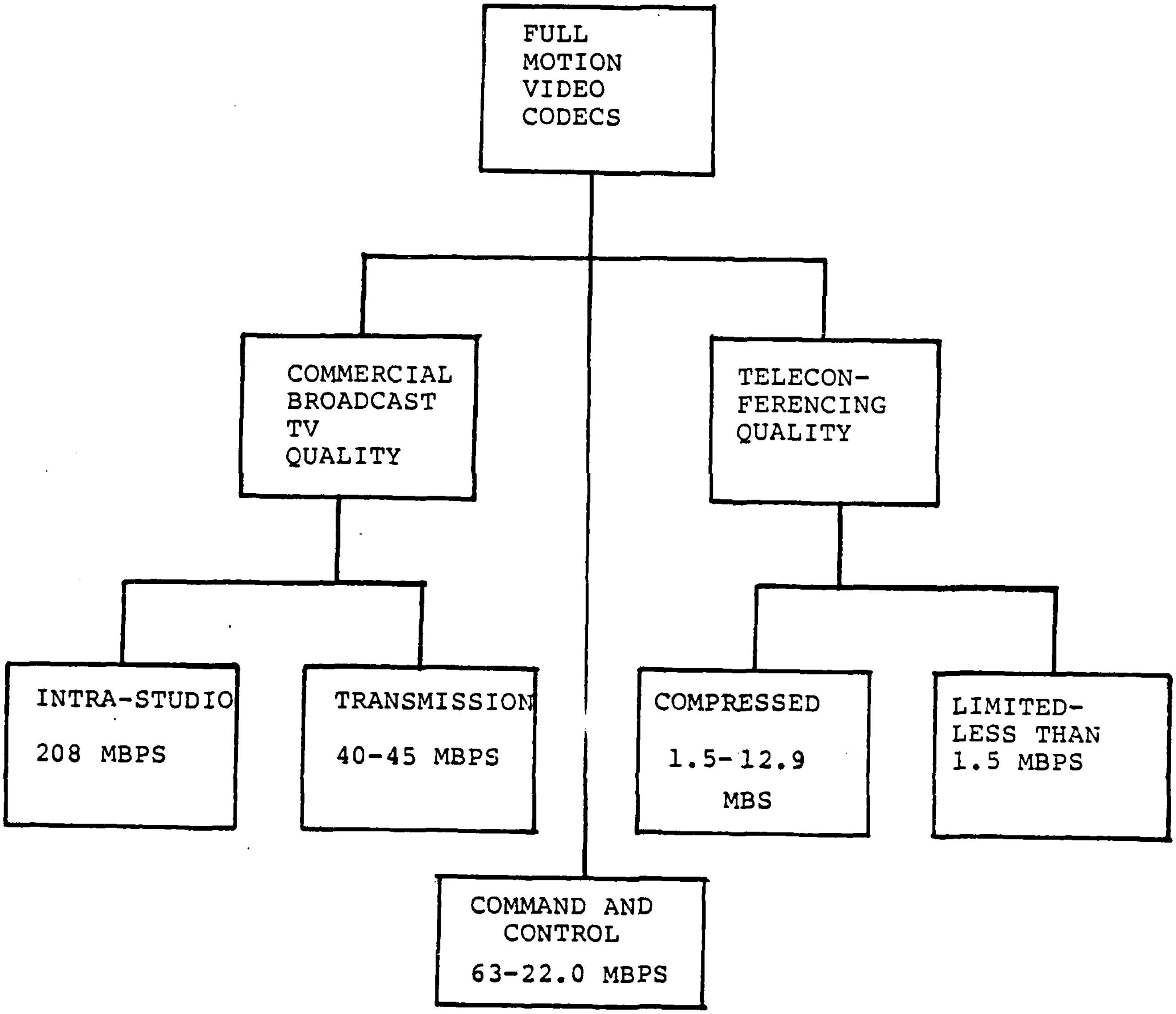
There are two distinctive types of compression algorithms in the marketplace today - transform and frame replenishment.

Compression Labs offers a codec which uses transform coding to reduce redundancy within a TV frame. This codec reduces redundancy from frame to frame by transmitting only alternate frames and interpolating the non-transmitted frames at the receiver. NEC and McMichael offer codecs based upon the frame replenishment concept originally developed at Bell Labs (References 1 through 10). The following Sections 3.2.2 and 3.2.3 discuss transform coding and frame replenishment coding in more detail.

The final step in the full motion video coding process is the performance of an error control function. In this process a small percentage (1% to 6%) of error control bits are added to the information bits. At the receiver an error correction function is performed using the transmitted error control bits.

As indicated above the most common transmission bit rate for teleconferencing is 1.5×10^6 bits/sec. Figure 3.2.2is a chart showing how this class of full motion video codec fits into the overall hierarchy of such systems. There are two types of codecs considered for use in the commercial broadcast TV industry. One type of codec operating at 208 mbps is used to digitally store very high quality TV images for TV studio application. If it is desired to digitally transmit a TV signal while maintaining broadcast signal quality a bit rate of

FIGURE 3.2.2 HIERARCHICAL CHART OF FULL MOTION VIDEO CODECS



approximately 40-45 mbps is required. Codecs of this type reduce redundancy within a TV frame and do not reduce redundancy from frame to frame. Figure 3.2.3 also shows that there is a class of codecs operating below 1.5 mpbs. It is difficult to characterize this group since there are proposals to operate down to 56 Kbps by severely reducing the picture resolution and quality of motion reproduction. Another special class of codecs is used in Command and Control (C^2) applications where very high quality of motion and resolution is needed. This class of codecs generally exhibits better performance than teleconferencing but somewhat less quality than broadcast.

3.2.2 Transform Coding

The purpose of this section is to describe a generic 1.5 MBS teleconferencing codec which employs transform coding. The parameters used in the discussion are generic, and it is not intended that they define a particular system or systems.

It is assumed a system of this type transmits 15 frames/sec, 480 lines/frame, and 512 pels/line. Assuming a transmission bit rate of 1.5×10^6 bits/sec. the equation provided below shows that the brightness value of each pel must be defined with only 0.4 bits on the average.

$$\frac{\text{Bits}}{\text{Pel}} = \frac{1.5 \times 10^6 \text{ bits/sec}}{480 \text{ lines/frame} \times 512 \text{ pels/line} \times 15 \text{ frames/sec}} = 0.4$$

It is assumed that the system presented here encodes each TV frame by transform coding as if it were an independent image. The above equation states that the transform coder must encode each frame such that the average number of bits/pel is 0.4. The remainder of this discussion presents a generic transform coding process to achieve this objective.

In the generic transform codec the input image of 512 x 480 pels is partitioned into an array of 32 x 30 subpictures, or blocks, where each block consists of 16 x 16 pels. The transform coding process is then imposed on each subpicture. The transform encoding of each block is performed in two, well-defined steps. The first operation is a linear transformation of the 16 x 16 subpicture into a set of Fourier coefficients which represent the spatial frequency characteristics of the block. The second step is to individually, digitally encode the Fourier coefficients for transmission. Data compression can be achieved in this encoding process because, in most natural images, many of the transform coefficients are of relatively low magnitude. Those coefficients often can be discarded entirely, or coded with a small number of bits with only negligible image distortion. Another advantage of coding in the spatial frequency domain rather than the original pel domain, is that it is now possible to more fully exploit the limitations of human vision. For example, when a Fourier Transform is employed, compression can be achieved by coarsely quantizing the higher order coefficients. This coarse quantization is permissible because of the insensitivity of the eye to this type of distortion. This thinning and quantization leads to the reduction of the number of bits required to represent an image.

The specific Fourier transform which is used most commonly in systems of this type is the Discrete

Cosine Transform (DCT). Figure 3.2.3 is an illustration of the two dimensional spatial frequencies which are convoluted with the input subpicture for the DCT. A total of 256 patterns are shown each corresponding to one transform coefficient. The patterns or coefficients have been numbered in the figure one through 256. Coefficient number one is a measure of the average brightness of the block. As a further example, coefficients 2 through 16 are measures of the amount of energy associated with vertical spectral lines of varying spatial frequency.

As explained above most of the energy in typical images is contained in those coefficients corresponding to low spatial frequencies. Therefore it is common to transmit the values of the coefficients in a sequence starting with coefficient number 1 in Figure 3.2.3 proceeding in a zig-zag pattern through the entire array of blocks, and ending with coefficient 256.

As explained above the transform codec must encode each pel with an average of 0.4 bits. Therefore each 16 x 16 block (on the average) will have approximately 100 bits available for its definition. This is typically accomplished by comparing the energy level of each of the 256 coefficients with a threshold and rejecting from transmission all those coefficients whose energy falls below the threshold. Those remaining coefficients

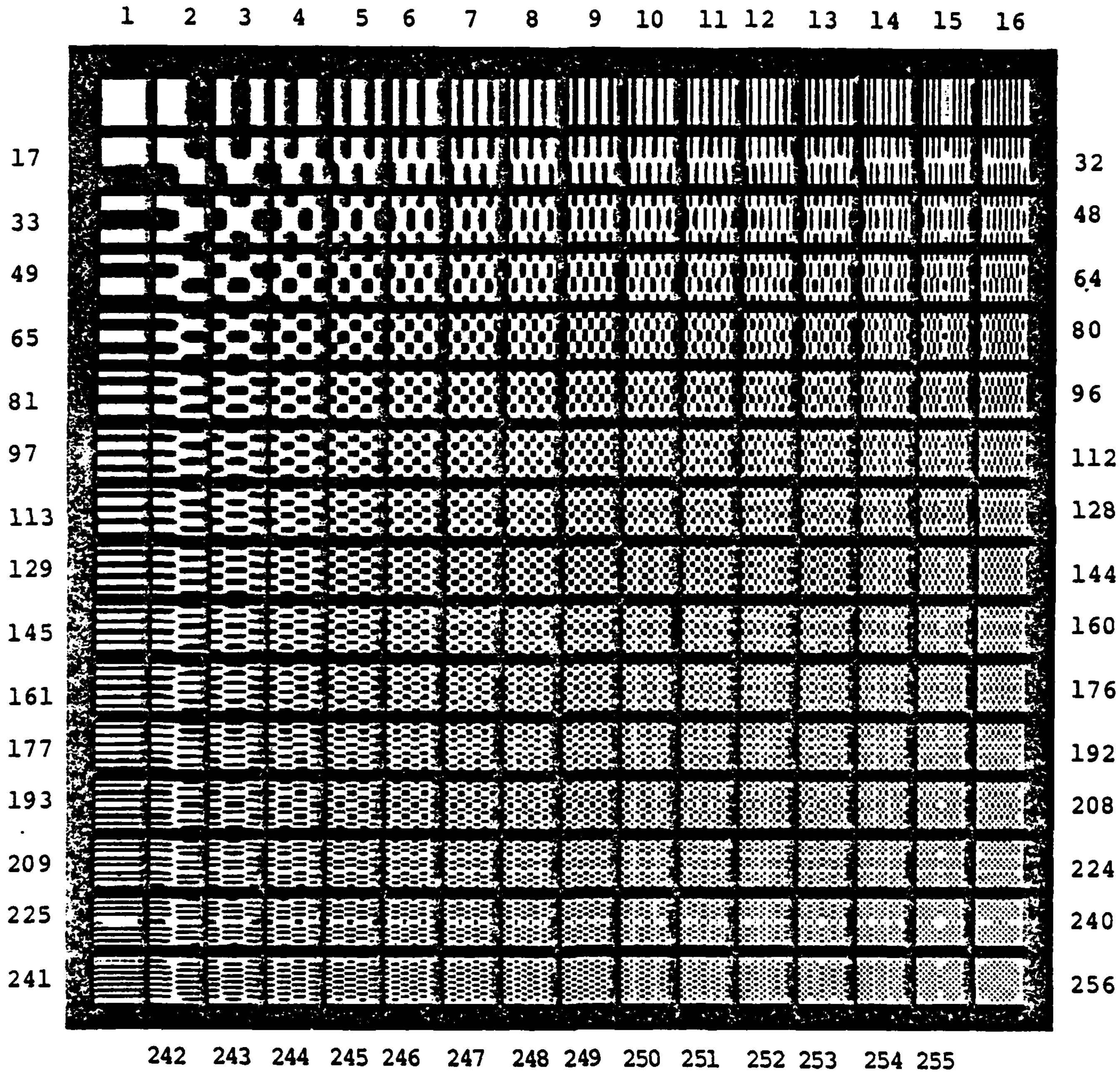


Figure 3.2.3 Two-Dimensional Cosine Transform Basis Functions

selected for transmission are digitally encoded and transmitted. Additional degrees of adaptation are achieved by dynamically shifting the level of the threshold as the image is transmitted. For example, if the top of the image is particularly complex requiring more than the nominal 100 bits/block for transmission, the threshold would be raised thereby reducing the number of coefficients to be transmitted in the lower portion of the image. On the other hand, if the top of the image requires below average number of bits for transmission, the threshold would be reduced to take full advantage of the remaining bits.

The above description of transform coding refers only to the transmission of monochrome imagery. However, as usual, the same technique is directly applicable to color TV since the transform codec can be used to encode 3 color components such as Y, R-Y, B-Y.

As stated above the preceding discussion assumed a fixed 2 to 1 interframe compression since the transmission frame rate is 15 frames/sec. It is possible to adopt the transform process to provide frame-to-frame compression as well as intraframe compression. For example if the informaiton in a 16 x 16 pel block does not change relative to the preceding frame it would not be transmitted. Hybrid techniques have also been proposed where the transform coefficients are transmitted by DPCM rather than PCM.

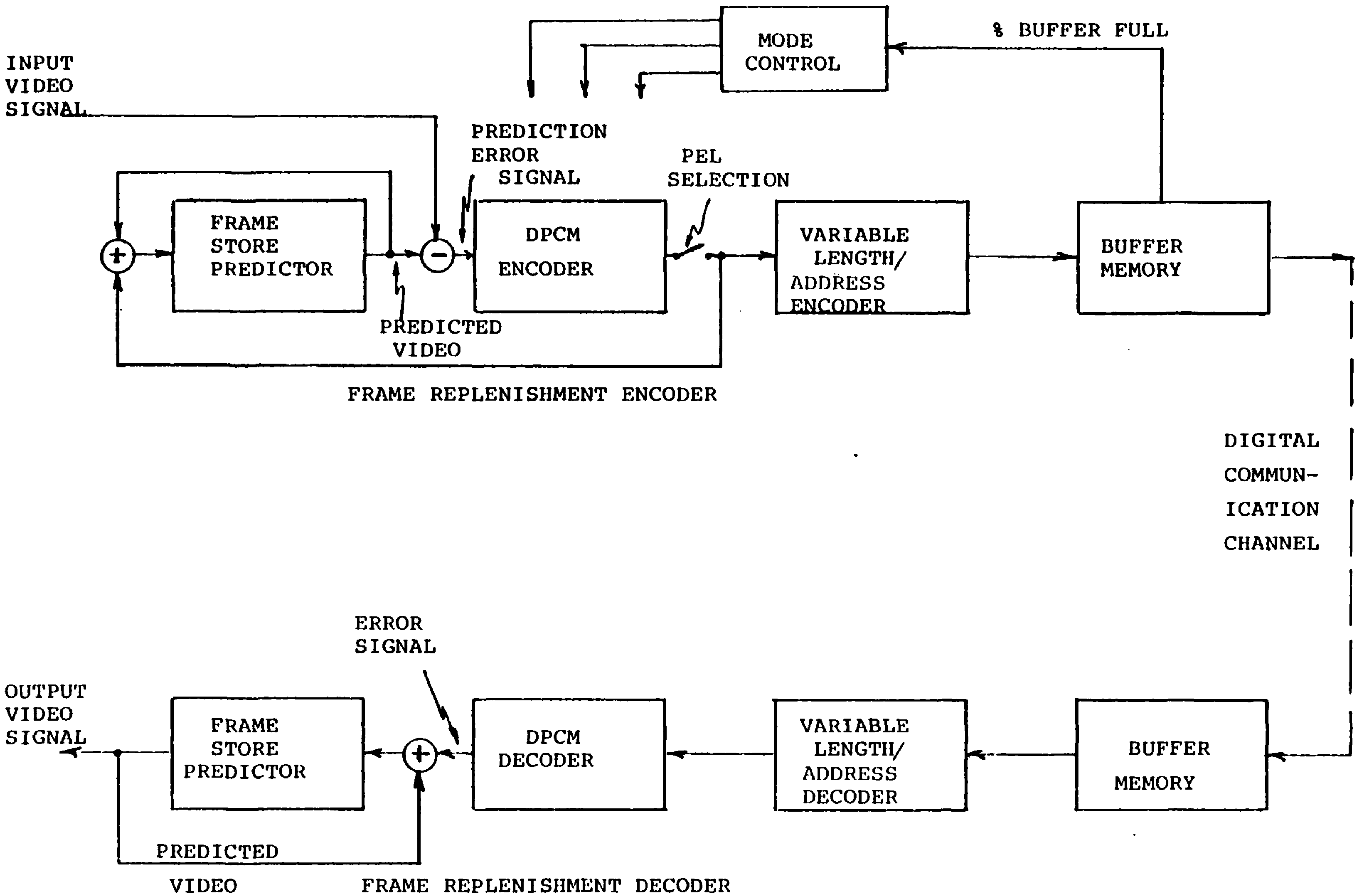
3.2.3 Frame Replenishment Coding

The original article on frame replenishment coding (1) was written by F. Mounts in 1969. Since that time the technical literature on this subject has been indeed voluminous (References 2 through 10). Most of the hardware which has been developed for the marketplace is based upon the frame replenishment concept. NEC and McMichael have developed units based on this principle, and DCC is developing a system of this type for the government.

Figure 3.2.4 is a block diagram of a generic Frame Replenishment codec system. As usual the decoder performs the complementary function of the encoder. The heart of the encoder is the function which stores a complete TV frame and uses this information to predict the present value of the input video signal. It should be noted that a frame store predictor, identical to that in the encoder, is also located in the decoder. The essence of the frame replenishment concept is to subtract the prediction signal from the input video signal and transmit the prediction error signal to the receiver where the prediction error is added to the predicted value.

The algorithm for this prediction function can vary greatly. It is typically based upon a combination of pels within the frame and in the previous frame. More

Figure 3.2.4 Frame Replenishment Coding



sophisticated predictors compute the velocity of moving areas of the image and transmit errors only when the input signal deviates from the predicted value based upon the motion computation.

In any case the prediciton error is encoded by a non-linear differential PCM encoder where small errors are encoded precisely and large errors are encoded coarsely. The switch following the DPCM encoder indicates that those pels which are accurately predicted are deleted from transmission. Only those pels which have changed "significantly" (ie. those pels where the predictor error exceeds a threshold) are selected for transmission. One function of the variable length/address encoder is to transmit the x,y address coordinates of those pels which are transmitted. The block also chooses the optimum code word to represent the transmitted error signal. Short code words are used for those error values which occur frequently and longer code words are used for those which occur infrequently.

A frame-to-frame coder generates data at a very uneven rate and it is necessary to smooth the data to a constant rate for transmission over the channel. This smoothing function is performed by the Buffer Memory. Even with a large buffer, the coder may generate information at a short-term average rate that is greater than the channel rate and there will be a tendency for the buffer to overflow. Feedback from the buffer is used in a number of ways to reduce the data generation rate. The various ways that the data rate entering the buffer can be reduced is listed below.

1. Modify the pel selection threshold such that any pel must have a larger prediction error in order to be selected for transmission.
2. Modify the quantization characteristics of the DPCM encoder to code the error signal more coarsely.
3. Reduce the spatial resolution of the transmitted areas of the image by subsampling. The intervening pels which are not transmitted are interpolated at the receiver.
4. Transmit only those pels which are part of field A. The pels in field B which are not transmitted are interpolated from field A.
5. Suspend replenishment and repeat the frame in memory.

As indicated earlier the frame replenishment decoder performs the inverse function of the encoder. The generic system described above was based upon the transmission of a monochrome video signal. When a color TV signal is to be transmitted the composite signal is typically divided into three spectral components——Y, R-Y, and B-Y. The frame replenishment system is then used to individually encode each of the 3 component signals after which they are multiplexed into one digital stream.

Section 3.0 REFERENCES

3.1 F.W. Mounts, "A Video Encoding System Using Conditional Picture-Element Replenishment," B.S.T.J., 48, No. 7 (September 1969), pp. 2545-2554.

3.2 J. C. Candy, M. A. Franke, B. G. Haskell, and F. W. Mounts, "Transmitting Television as Clusters of Frame-to-Frame Differences." B.S.T.J., 50, No. 6 (July-August 1971), pp. 1889-1917.

3.3 B. G. Haskell, P. L. Gordon, R. L. Schmidt, and J. V. Scattaglia, "Interframe Coding of 525-Line, Monochrome Television at 1.5 MBS," IEEE Trans. Commun., COM-25, No. 10 (October 1977), pp. 1339-1344.

3.4 T. Ishiguro, K. Iinuma, Y. Iijima, T. Koga, S. Azami, and T. Mune, "Composite Interframe Coding of NTSC Color Television Record (Dallas, Texas November, 1976), 1, pp. 6.4-1 to 6.4-5.

3.5 B. G. Haskell, "Frame Replenishment Coding of Television," a chapter in Image Transmission Techniques, W. K. Pratt, Ed., New York: Academic Press, 1978.

3.6 F. Rocc, "Television Bandwidth Compression Utilzing Frame-to-Frame correlation and Movement Compensation," Symposium on Picture Bandwidth Compression (M.I.T., Cambridge, Mass., 1969), Gordon and Breach, 1972.

3.7 J. O. Limb and J. A. Murphy, "Estimating the Velocity of Moving Images from Television Signals," Computer Graphics and Image Processing, 4 (1975), pp 311-327.

3.8 J. D. Robbins and A. N. Netravali, "Motion-Compensated Television Coding," B.S.T.J., 58, No. 3 (March 1979), pp. 631-670.

3.9 B. G. Haskell, "Differential Addressing of Clusters of Changed Picture Elements for Interframe Coding of Video-telephone Signals," IEEE Trans. Commun. (January 1976), pp. 140-144.

3.10 J. D. Robbins and A. N. Netravali, "Motion-Compensated Television Coding," Part II, B.S.T.J., (Sept. 1979).

3.11 "Transform Coding," a Chapter in Image Transmission Techniques, W. K. Pratt, Ed., New York: Academic Press, 1978.

4.0 Vendor and Market Analysis (Task 1)

4.1 Approach

The purpose of this task was to obtain technical information about all known motion codecs, and motion teleconferencing systems installed and being planned. Initially, a letter was sent to organizations and vendors who had indicated an interest in fabricating motion codecs. A detailed technical questionnaire and subsequent supplemental questionnaire were then sent to those vendors who indicated that they were manufacturing and/or developing motion codecs.

Similarly, organizations and agenices who have installed or who are planning to install motion digital video teleconferencing systems were contacted to obtain technical information about the system. The remainder of Section 4.0 describes the information obtained from these efforts.

4.2 Codec Vendor Questionnaire

The initial questionnaire constructed to obtain information from the motion codec vendors was composed of 5 parts as follows:

Part 1. Product Nomenclature and General Description

Part 2. Technical Specifications - Input and Output Signals

Part 3. Technical Specifications - Performance

Part 4. Physical Description and Specifications

Part 5. Other Product Data

A supplemental questionnaire was also sent to each vendor requesting more detailed data about the composition of the transmitted data bit stream. These details are essential for determining the feasibility of establishing a possible codec transmission standard.

The instructions provided to each vendor indicated that the response to the questionnaire would be used to compare codecs and "that only approved and non-proprietary information and data will be used in the study."

Appendix C contains the letter and instructions sent to each codec vendor. Also in Appendix C is an outline of the initial and supplemental questionnaires provided to the vendors and agencies involved in codec development. The following sections provide a brief description of the codec information which was solicited from the vendors.

4.2.1 Part 1. Product Nomenclature and General Description

The purpose of Part 1 was to obtain information about the vendor including point of contacts, address, and location. Secondly, specific data about the codec itself was asked including the codec name, model, date introduced, number of units installed and locations.

Next, pricing information was solicited on the basic unit, options, maintenance, spares, and training. Questions concerning the product life were asked including expected product life period, anticipated improvements or modifications, growth potential and any other comments or information on product life.

Details about warrantees and services were solicited. Particularly, questions on maintenance, repairs, spares, and training were asked.

4.2.2 Part 2. Technical Specifications - Input and Output Signals

Data about the input and output codec signals was requested in Part 2. Characteristics of the input and output video signals was to be supplied including standards, synchronization levels, and impedances. Similar data was asked about the input and output audio signals also. Details were supplied about the codec digital output signals including bit rates and formats.

Information was asked about other digital data ports to the codec and their signal characteristics.

4.2.3 Part 3. Technical Specifications - Performance

This section of the questionnaire contains pertainent questions about the codec specifications and its stated performance. Parameters such as number of pixels, sampling rates, precision of encoding and frequency response were asked. Performance as measured in terms of the more usual analog measurements including differential gain and phase, signal-to-noise ratio, and luminance - chrominance gain and delay inequalities were to be supplied.

Motion performance was to be stated for various amounts of pixels changing between frames ranging from 10% to 100%. The effects of panning and zooming were to be stated.

The codec performance for various data link error conditions ranging from a bit error rate of 10^{-6} to 10^{-3} was solicited.

Specific questions were asked about the compression techniques employed in the codec. The general type of compression including intraframe and interframe should be listed. Compression ratios, descriptions, and growth potential were also to be contained in the response.

Similar kinds of requested data were asked about the performance of the audio portion of the codec.

4.2.4 Part 4. Physical Description and Specifications

This part of the questionnaire was included to obtain information about the physical codec specifications, power requirements, environmental operation, and connector interfaces in order to determine common characteristics amoung the codecs as well as to point out any unusual features which could possibly affect future standardization efforts.

4.2.5 Part 5. Other Product Data

The following kinds of data concerning codecs was solicited in this part of the questionnaire. A description of codec status indicators and alarms, built-in test equipment, and operator controls was to be provided. Additionally, the use of encryption or scrambling functions was to be detailed and its effects upon the transmission protocol.

Copies of manuals, product documentation, brochures, and technical notes were requested from all vendors.

4.2.6 Supplemental Questionnaire

The supplemental questionnaire sent to the codec vendors requested further detail about the transmitted data stream. Descriptions of frame and word length, bit rates, compatibility with ATT T1 protocol, composition of the frame, error correction, and encryption were asked. Further, recommendations for adopting a transmission standard at various bit rates was requested.

4.3 Codec Vendor and Organization Participants

4.3.1 List of Initial Contacts

The following organizations were contacted initially to solicit information about motion codecs for this codec study. Appendix D contains the addresses and points of contact of vendors and organizations which were contacted for information on motion video teleconferencing equipments and systems.

1. Compression Labs, Inc.
2. NEC America, Inc.
3. MACOM Laboratories
4. Widergren Communications, Inc.
5. E-Systems, Inc.
6. Motorola, Inc.
7. Digital Communications Corporation
8. American Telephone and Telegraph Company
9. Decisions and Designs, Inc.
10. National Security Agency
11. USA CECOM
12. McMichael Limited
13. British Telecom International
14. American Bell, Inc.
15. American Electronic Laboratories
16. Colorado Video, Inc.
17. Bell and Howell

4.3.2 Organizations Receiving Questionnaires

The organizations shown in the following Table 4.3.2 were asked to complete the detailed questionnaires. The final status of each questionnaire is shown in the right column.

Table 4.3.2
Responses to Questionnaire

Organization/Vendor	Completed	Did Not Complete
1. Compression Labs, Inc.	X	
2. NEC America, Inc.	X	
3. Widergren Communications, Inc.	X	
4. M/A-Com DCC, Inc.	X	
5. AT&T	X	
6. National Security Agency		X
7. U.S. Army CECOM		X
8. British Telecom International	X	

4.4 Vendor Demonstrations

As a follow-up to the questionnaires received from the codec vendors, demonstrations of codec hardware and review of video tapes were observed by DIS personnel as listed below.

1. Compression Labs, Inc.

   *Model VTS 1.5 at 1.5 MBS.

   *Sketch encoder at 19.2 KBS.

2. NEC America, Inc.

   *Model NETEC-X1 at 1.5 MBS.

   *Model NETEC-X1 (MC) at 1.5 MBS.

3. GEC-McMichael, Ltd.

   *Model 2/1.5 MBITS Video-Conference Codec at 2.048 MBS.

4. Widergren Communications, Inc.

   *Model VCU-2/56 at 56 KBS, 112 KBS, 224 KBS.

5. AT&T PMS

   *Model NETEC - X1.5/3 at 3.0 MBS.

6. M/A - Com DCC, Inc.

   *Video tape simulation at 1.5 MBS.

4.5 Existing Motion Teleconferencing Systems

There are several motion video teleconferencing systems in operation using various codecs. Generally, these exisiting systems can be catagorized by overall performance quality with a corresponding transmission bit rate. The following Table 4.5.1 summarizes the majority of these teleconferencing systems, indicating transmission rates and codec manufacturer.

TABLE 4.5.1 EXISTING DIGITAL MOTION TELECONFERENCING SYSTEMS

Organization	Transmission Bit Rate	Codec Manufacturer	Number of Nodes	Comments
1. U.S. Army	36.8 MBS	American Electronics Laboratories	2	High Performance Quality
2. U.S. Army	36.8 MBS	Philco-Ford Corporation	2	High Performance Quality
3. AT&T-PMS	3.0 MBS	Nippon Electric	12	Teleconferencing-type Quality
4. Allstate Insurance Co.	1.5 MBS	Nippon Electric	2	"
5. NASA	1.5 MBS	Compression Labs	2	"
6. Atlantic Richfield Co.	1.5 MBS	Nippon Electric	2	"
7. American General Insurance	1.5 MBS	Compression Labs	4	"
8. ISA Communications	1.5 MBS	Compression Labs	2	"
9. Aetna Insurance	1.5 MBS 1.5 MBS	Nippon Electric Compression Labs	2	"
10. Citicorp	1.5 MBS	Compression Labs	2	"
11. AF Personnel	19.0 KBS	Compression Labs	2	Poor Quality, Black/ White Only (Not operational yet)

4.6 In-place System Demonstrations

Demonstrations of motion video teleconferencing systems were observed by DIS personnel as listed below.

1. US Army - 2 independent systems at 36.8 MBS
2. AT&T PMS - at 3.0 MBS
3. Allstate Insurance - at 1.5 MBS
4. NASA - at 1.5 MBS
5. ISA Communications - at 1.5 MBS
6. Aetna Insurance - 2 channels at 1.5 MBS each

In addition to the above, demonstrations of motion codecs installed in video teleconferencing rooms at Satellite Business Systems and at Nippon Electric Compnay were also observed.

4.7 Future Teleconferencing Systems

During the course of this study, it was determined that there are several digital motion TV teleconferencing systems planned or are being planned for implementation by the agencies of the Federal Government and by commercial organizations. This information is significant because it appears that little or no coordination between agencies has occurred; thus, there is little likelihood that these systems will be standardized or compatible with each other.

Table 4.7.1 is a compilation of some (not complete) government systems based upon information (Fall 1982) provided to DIS personnel. It should be understood that much of this data is preliminary and has not received final approval or funding. Table 4.7.2 contains a partial listing of teleconferencing systems currently being considered only for implementation by Commercial organizations.

TABLE 4.7.1

Partial Listing of Future Government Digital Motion Teleconferencing Systems in Planning

Organization/ Agency	Anticipated Number of Nodes	Expected Communication System	Comments
1. Darcom-Army		COMSATCOM	Final planning and funding stage
2. Army Chief of Staff		COMSATCOM	Final planning stage
3. Air Force Systems Command		COMSATCOM	Trial testing planned
4. DCA (Network 1)	8	Common Carrier	In planning stage
5. DCA (Network 2)	5	COMSATCOM	Very preliminary planning
6. GSA (WTIC)		Common Carrier	In detailed design stage. Report issued June 1982.
7. DOE	3	Western Union	Status unknown
8. GSA (Federal Tele-Comm)	Unknown	Unknown	Unknown
9. Army WAWS Expansion		Western Union	In Planning
10. Air Force CSOC	14	Competitive	Current bidding for system design contractor as of 3/31/83.
11. NASA Headquarters	Unknown	Common Carrier	Report being prepared by NASA.

TABLE 4.7.2

Partial Listing of Future Commercial Digital Motion Teleconferencing Systems in Planning

Organization	Approximate Number of Nodes	Expected Communication System	Comments
1. Allstate Insurance	28	American Satellite	Expansion of existing system
2. AT & T PMS	50	AT & T	Expansion of existing PMS system
3. ISACOMM	10	Satellite Business Systems	Expansion of existing system
4. Aetna Insurance	2	Satellite Business Systems	Expansion of existing system
5. Ford Aerospace	unknown	unknown	Filed with FCC
6. Allstate Insurance	unknown	unknown	Filed with FCC
7. MACOMNET	unknown	unknown	Have existing freeze-frame system
8. International Telephone & Telegraph	3	unknown	Building conference rooms

5.0 Comparison of Full Motion Video Codecs (Task 2)

5.1 Approach

In this task the data collected in Task 1 questionnaires was catalogued and comparisons of the various codecs has been made and reported in this section. It should be pointed out that the data used in these comparisons has been supplied by each codec vendor - no data or specifications have been verified by an independent source.

5.2 Key Specification and Performance Parameters

Although the questionnaires submitted to the codec vendors requested extensive information about each codec, there are some specifications and performance criteria which are deemed more important to overall codec performance. These particular specifications will therefore be compared in the remainder of Section 5.0 of this report.

5.3 Abbreviations

In the tables and graphs contained in this section the following abbreviations are used to identify the codec questionnaire respondees:

CLI	Compression Labs, Inc.
NEC	NEC America, Inc.
ATT	American Bell, Inc.
DCC	M/A-Com DCC, Inc
WID	Widergren Communications, Inc.
MCM	GEC-McMichael, Ltd/British Telecom International

The additional abbreviations below are used to indicate vendor responses to some questions.

CP	Company Proprietary
NA	Not Available
NR	No Response
TBD	To Be Determined

The questionnaire response submitted by American Bell, Inc, indicated that their codec was a NETEC 1.5/3 which is furnished by NEC America, Inc.

5.4 Resolution Comparisons

5.4.1 Video Input Signals

Table 5.4.1 contains the comparisons of the input video signals to the various codecs. All codecs accept and provide the NTSC standard television signal. Additionally, some codecs will also operate with the more tolerant RS170 monochrome TV standard as shown in the table.

Similarly, all codecs specified an input video signal of 1.0 volt peak to peak with 75 ohm impedance and an unbalanced input line. None require an auxiliary sync input signal.

In summary, there appears to be universal agreement on the following specifications.

a. Input Video Signal -NTSC

b. Voltages and impedance -1.0 volt peak to peak, 75 ohms

c. Type of input signal line - Unbalanced

d. Sync input requirement - None

Table 5.4.1 COMPARISON OF VIDEO INPUT SIGNALS

Specification	CLI	NEC	ATT	DCC	WID	MCM
1. Meets Video Standards (NTSC, RS170)	NTSC, RS170	NTSC	NTSC	NTSC, RS170	NTSC, RS170	NTSC, PAL, RGB, CCIR Rec. 472
2. Color/Monochrome	Color or Monochrome	Color or Monochrome	Color	Color and Monochrome	NR	Both
3. Number of inputs	4 Video inputs 6 w/ graphics option	2 inputs (1 for motion, 1 for document)	1 input	NA	1 input	1 input
4. Voltages and impedance	1 V p-p 75 Ohms	1 V p-p 75 Ohms	1 V p-p 75 Ohms	1V (-40 to +100 IRE)	1V p-p 75 Ohms	1V p-p 75 Ohms
5. Balanced/unbalanced	Unbalanced	Unbalanced	Unbalanced	75 ohms Unbalanced	Unbalanced	Both
6. Requires sync input	No	Not Necessary	No	No	No	No, except with RGB input
7. Description of sync input	-	NTSC Composite Sync	NR	-	-	75 Ohm composite sync input 0.3-2V p-p
8. Video Test Input Provided	No	Automatic Diagnosis Option provides test signal	NR	-	No	NR
9. Any restrictions on Video Input	-	Accuracy of Horizontal Freq. 130 PPM	Horiz. Feq. locked to color subcarrier even for monochrome	-40 to +133 IRE	Must be within RS-170 specs	NR

5.4.2 Vendor Resolution Data

The data presented in Table 5.4.2 contains information about the basic operating parameters of the codecs. Of those codec vendors who provided data, it is noted that all use component coding of a luminance and two chroma video signals as opposed to composite coding. The McMichael (MCM) data represents European TV standards (625 vertical scanning lines) and therefore can not be directly compared to the other codec vendors whose data is for 525 vertical scanning lines. It is further noted that the Widergren (WID) response is based on a transmission rate of 224 KBS, the McMichael response on a 2.048 MBS transmission rate and the CLI, NEC, ATT, DCC responses on a 1.544 MBS transmission rate.

Table 5.4.2 Comparison of Resolution Parameters

Parameter/Specification	CLI	NEC	ATT	DCC	WID	MCM
1. Horizontal Sampling Rate (luminance)	7.2MHZ	7.2 MHZ	NR	CP	10.7MHZ	5.0MHZ-Face 12.5MHZ-Graphics
2. Horizontal Pixels (luminance)	368	455	NR	CP	256	320
3. Vertical Sampling Rate (luminance)	525	525	NR	CP	240 lines	286/575 lines
4. Vertical Pixels (luminance)	480	525	NR	CP	240	286/575 lines
5. Luminance Sampling Rate	7.2MHZ	7.2MHZ	NR	CP	10.7MHZ	5.0/12.5 MHZ
6. Chrominance Sampling Rate(s)	1.8MHZ	1.2MHZ	NR	CP	I-1.2MHZ Q-600KHZ	0.5/3.125 MHZ
7. No. of Chrominance Channels	2	1 channel in line-sequential	NR	CP	2	2
8. Luminance Encoding Precision	8 bits	8bits/ sample	NR	CP	8 bits/ pel	8 bits
9. Chrominance Encoding Precision	6 bits	8 bits/ sample	NR	CP	8 bits/ pel	8 bits
10. Coding Frame Rate	15 frames/ sec.	30 frames/ sec.	NR	NA	10 frames/ sec.	NR

5.4.3 Summary of Resolution Data

In comparing the resolution data submitted for the motion codecs, only 2 vendors provided data at 1.54 MBS. It appears that CLI and NEC provide pixels for "full" frame image resolution while WID and MCM appear to provide approximately ½ horizontal and ½ vertical pixels or ¼ frame resolution - again noting that the WID transmission rate is about 1/6 of 1.54 MBS. However, the MCM transmission rate is 2.048 MBS which is close to 1.54 MBS. It appears that the MCM image at a comparable 1.54 MBS transmission rate has ¼ of the overall image pixels compared to the CLI and NEC codecs.

Table 5.4.3 suggests some possible preliminary parameters based upon the commonality of the comparative data in Table 5.4.2.

Table 5.4.3 Preliminary Resolution Parameters for 1.54 MBS Transmission

Horizontal Pixels	- 368 minimum
Vertical Pixels	- 480
No. of Chroma Channels	- 2
Chroma Encoding Precision	- 6 bits/pixel minimum
Luminance Encoding Precision	- 8 bits/pixel

5.5 Analog TV Performance Measurement Comparisons

5.5.1 Applicability to Digital Codecs

There is much discussion among digital TV engineers about the significance of analog TV performance measurements, commonly used in the broadcast TV industry to measure TV quality, applied to digital television codecs. Without entering the arguement, it does appear that the standards used in analog TV systems for such video test signal measurements as differential phase and gain, video frequency response, etc. provide the upper limit that a digital TV codec could achieve. In other words, codecs in general will not perform as well.

Nevertheless, there are useful purposes in employing video test signals to characterize television systems; they can be used to perform comparative evaluation of properly functioning equipments and can be used to diagnose malfuncting equipments. Relative standards among the codecs thus can be important.

5.5.2 Vendor Measurement Data

Table 5.5.1 contains the vendor supplied analog performance measurements for various video test signals. Again it is noticed that the only vendors providing a complete set of measurement data are CLI and NEC.

Table 5.5.1 Comparison of Video Test Signal Meaurements

Video Test	CLI	NEC	ATT	DCC	WID	MCM
1. Video Frequency Response	3db down at 2.7MHZ	$\pm$0.5db, 0.5 to at least 2MHZ	NR	NA	2.2MHZ	2.5MHZ Face 6.25MHZ Graphics
2. Differential Gain	less than 6%	less than 8%	less than 8% (Quantization averaged)	NA	TBD	Irrelevant
3. Differential Phase	less than 6%	less than 4 degrees	less than 4 degrees (Quantization averaged)	NA	TBD	Irrelevant
4. Luminance-Chrominance Gain Inequality	less than 5%	less than 14 IRE units	less than 14 IRE units	NA	TBD	Irrelevant
5. Luminance-Chrominance Delay Inequality	less than 50nsec	less than 54nsec	less than 54 nsec	NA	TBD	Irrelevant
6. Signal-to-Quantizing Noise Ratio	45 db	Greater than 50db (weighted)	NR	NA	TBD	Irrelevant
7. Short Time Wave form Distortion	less than 3%	less than 14 IRE units	less than 14 IRE units, peak-to-peak ringing	NA	TBD	Irrelevant
8. Field Time Waveform Distortion	less than 3%	less than 3 IRE units	NR	NA	TBD	Irrelevant
9. Line Time Waveform	less than	less than 2	NR	NA	TBD	Irrelevant

5.5.3 Summary of Measurement Data

In reviewing the data supplied by CLI and NEC, it appears that both codec responses to the video test signals are similar. A word of caution is noted as the exact measurement technique, procedure, and test equipment used were not specified by the vendors.

5.6 Motion Performance Comparisons

5.6.1 Discussion

The comparison evaluation of motion performance of codecs is at best at this time an almost totally subjective process. This is true because of the lack of a standard motion measuring technique which would provide objective simultaneous measurements of motion response, image resolution, and color fidelity.

A codec can respond to motion in several different ways in an attempt to minimize perceptible degradation. Some codecs may reduce the resolution of the image or the portion of the image which is moving while maintaining fairly good motion response. Other codecs may reduce the basic frame rate of the codec while retaining good resolution. And there are codec techniques which attempt to predict motion or utilize a combination of techniques.

To further complicate the issue, no minimum acceptable motion standards for teleconferencing applications have been established. A close-up view of a single person may require better motion response, for instance, than a distant view of several persons.

5.6.2 Vendor Motion Responses

In order to obtain some standard measure of codec motion response, each codec vendor was asked a series of questions about performance under various amounts of motion between TV frames as expressed in percent of pixels. These results are tabulated in the following tables. It should be again noted that the CLI and NEC responses are based upon 1.544MBS transmission, MCM upon 2.048MBS transmission, and WID upon 256KBS transmission. The NEC response is based upon motion compensation incorporated in the codec.

TABLE 5.6.1 Comparison of Motion Performance

Condition 1. 10% pixels change between frames

Motion Performance Questions	CLI	NEC	ATT	DCC	WID	MCM
1. Perceptible motion degradation	None	None	NR	CP	No	None
2. Perceptible artifacts	None	None	NR	CP	No	None
3. Perceptible flicker	15F/sec	None	NR	CP	No	None
4. Perceptible distortion in moving objects	None	None	NR	CP	Yes	None
5. Perceptible color degradation	None	None	NR	CP	No	None
6. Perceptible resolution degradation	None	None	NR	CP	No	None
7. Any other effects	NR	None	NR	CP	NR	None

TABLE 5.6.2 Comparison of Motion Performance

Condition 2. 25% pixels change between frames

Motion Performance Questions	CLI	NEC	ATT	DCC	WID	MCM
1. Perceptible motion degradation	None	None	NR	CP	No	Negligible distortion
2. Perceptible artifacts	None	May perceive noise	NR	CP	No	Negligible distortion
3. Perceptible flicker	15F/sec	No	NR	CP	No	Negligible distortion
4. Perceptible distortion in moving objects	None	No	NR	CP	Yes	Negligible distortion
5. Perceptible color degradation	None	No	NR	CP	No	Negligible distortion
6. Perceptible resolution degradation	None	No	NR	CP	No	Negligible distortion
7. Any other effects	NR	No	NR	CP	NR	Negligible distortion

TABLE 5.6.3 Comparison of Motion Performance

Condition 3. 50% pixels change between frames

Motion Performance Questions	CLI	NEC	ATT	DCC	WID	MCM
1. Perceptible motion degradation	None	No	NR	CP	Yes	None
2. Perceptible artifacts	None	May perceive resolution change	NR	CP	Yes	None
3. Perceptible flicker	15F/sec	No	NR	CP	No	None
4. Perceptible distortion in moving objects	None	No	NR	CP	Yes	Loss of Resolution
5. Perceptible color degradation	None	No	NR	CP	No	None
6. Perceptible resolution degradation	None	May go into half resolution mode	NR	CP	No	2:1 sub sampling
7. Any other effects	NR	No	NR	CP	NR	Some frozen noise

TABLE 5.6.4 Comparison of Motion Performance

Condition 4. 100% pixels change between frames

Motion Performance Questions	CLI	NEC	ATT	DCC	WID	MCM
1. Perceptible motion degradation	None	May perceive jerkiness	NR	CP	Yes	None
2. Perceptible artifacts	None	May perceive resolution changes	NR	CP	No	Sub-sampling visible
3. Perceptible flicker	15F/Sec	No	NR	CP	No	None
4. Perceptible distortion in moving objects	None	May perceive jerkiness	NR	CP	Yes	Loss of resolution
5. Perceptible color degradation	None	No	NR	CP	No	None
6. Perceptible resolution degradation	None	May go into a half resolution mode	NR	CP	No	4:1 sub-sampling
7. Any other effects	NR	No	NR	CP	NR	Increased frozen noise

5.6.3 Summary of Motion Performance Data

The CLI response to the motion questions under various amounts of pixel changes indicates no perceptible motion degradations. This response is due to the fact that the CLI codec does not employ an interframe compression technique. However, CLI reports that there is a 15 frame/sec flicker associated with all motion conditions. Of the vendors who provided a response with 10% pixels changing between successive frames, Condition 1, Table 5.6.1, all claim no motion degradations except WID who indicated a perceptible distortion in moving objects.

When 25% pixels are changed between frames, condition 2, Table 5.6.2, NEC reports that a perceptible noise may be observed. The other vendor responses were the same as for 10% changes.

In Table 5.6.3 for 50% pixel changes, NEC, MCM, and WID all report perceptible degradations primarily in reduced resolution and/or distortion in the objects which are moving.

When 100% of the pixels change between frames, NEC, MCM, and WID report considerable perceptible degradations in picture quality. The above reports are indeed valid based upon the visual observations by DIS personnel of the vendor codecs under the various conditions described above.

5.7 Vendor Compression Technique Comparisons

5.7.1 Overview

Brief descriptions of each vendors' codec is contained in this section based on information supplied by the vendor. Where available, detail about the various coding sub-systems is provided. Performance limitations of the codecs are listed. A measure of the codec/compressor complexity is provided by comparing size, weight and power requirements.

Additional information was solicited concerning product life, planned improvements, and future growth potential. Information about pricing and delivery is detailed. Other data regarding spares, maintenance, training and connector interfaces was received but is too detailed to be listed. Finally, a vendor supplied bibliography and reference list is provided.

5.7.2 Compression Descriptions

In Section 3.2 general descriptions of various motion compression techniques was presented. It is, of course, realized that the compression algorithm and its implementation form the heart of the motion codecs studied in this contract. The ability to remove, eliminate, or reduce the amount of digital video TV information to be transmitted at a given bit rate while maintaining an acceptable displayed picture is the goal of vendors in the codec competition for video teleconferencing.

None of the codec vendors have implemented compression techniques which are compatible with any other vendor at this time. However, three vendors, NEC, MCM, WID have utilized a similar compression concept known as conditional or frame replenishment. ATT is listed as a codec vendor although they use a NEC codec which ATT apparently modify. As described in Section 3.2, this concept transmits video data only for pixels which change from frame to frame. Table 5.7.1 compares the various aspects of compression technology as implemented in the vendor codecs.

5.7.3 Codec Performance Limitations

Table 5.7.2 is a summary of the overall performance limitations of the codecs for the models listed. For the codecs operating at 1.544 MBS transmission rate, the NEC codec has the highest number of horizontal pixels (455) while the MCM codec has the lowest (286) number of pixels. Both NEC and CLI have a full vertical frame of 480 pixels (lines) while again the MCM has the smallest number of pixels.

Looking at the maximum number of pixels to represent (resolve) an image, the NEC codec clearly has the most at 218,400 pixels while the CLI codec has 176,640 pixels or 41,760 less pixels (approximately 19%). However, the MCM codec in the motion (face) mode has substantially less pixels per image than the NEC and CLI codecs. The total pixels per frame also provide an insight into the codec

TABLE 5.7.1 Comparison of Compression Techniques

NR-No Response
CP-Company Proprietary
NA-Not Available
TBD-To Be Determined

Parameter, Specification, or Performance	Compression Labs	Nippon Electric	McMichael Ltd.	Macom DCC	ATT PMS	Widcom
1. Codec Name/Model	VTS 1.5 400188 400422 400423	NETEC-X1 (MC)	2/1.5MBS Video-Conference Codec	NR	NETEC 1.5/3	VCU-2/56
2. Vendor Description of Compression Technique	2-D Cosine Transform, scene adaptive coding	DPCM, frame replenishment motion comp-ensation are adaptively introduced	Conditional replenish-ment with 2D prediction	CP	Frame Re-plenishment	Huffman coded, 2-D cosine transform, conditional replenishment
3. Basic analog-to-digital conversion coding						
a. Luminance	8 bits	8 bits/ sample	8 bits	CP	NR	8 bits/pel
b. Chroma	6 bits	8 bits/ sample	8 bits	CP	NR	8 bits/pel
4. Intraframe Coding	Cosine transform, scene adap-tive coding	Line seq-uential trans-mission of chroma signals (½ vertical resolution)	NR	CP	NR	NA

Table 5.7.1 (page 2)

	Compression Labs	Nippon Electric	McMichael Ltd.	Macom DCC	ATT PMS	Widcom
5. Interframe Coding	Eliminates alternate frames	Movement detector and block coder	Movement detection and DPCM	CP	NR	NA
6. Entropy Coding	Variable length coding	Variable word length coding	Variable length coding	CP	NR	NA
7. Compression Ratio claimed at 1.544 MBS	60:1	48:1	40:1 at 2.048 MBS	CP	NR	300:1 at 256 KBS

Table 5.7.2 Compression/Codec Performance Limitations

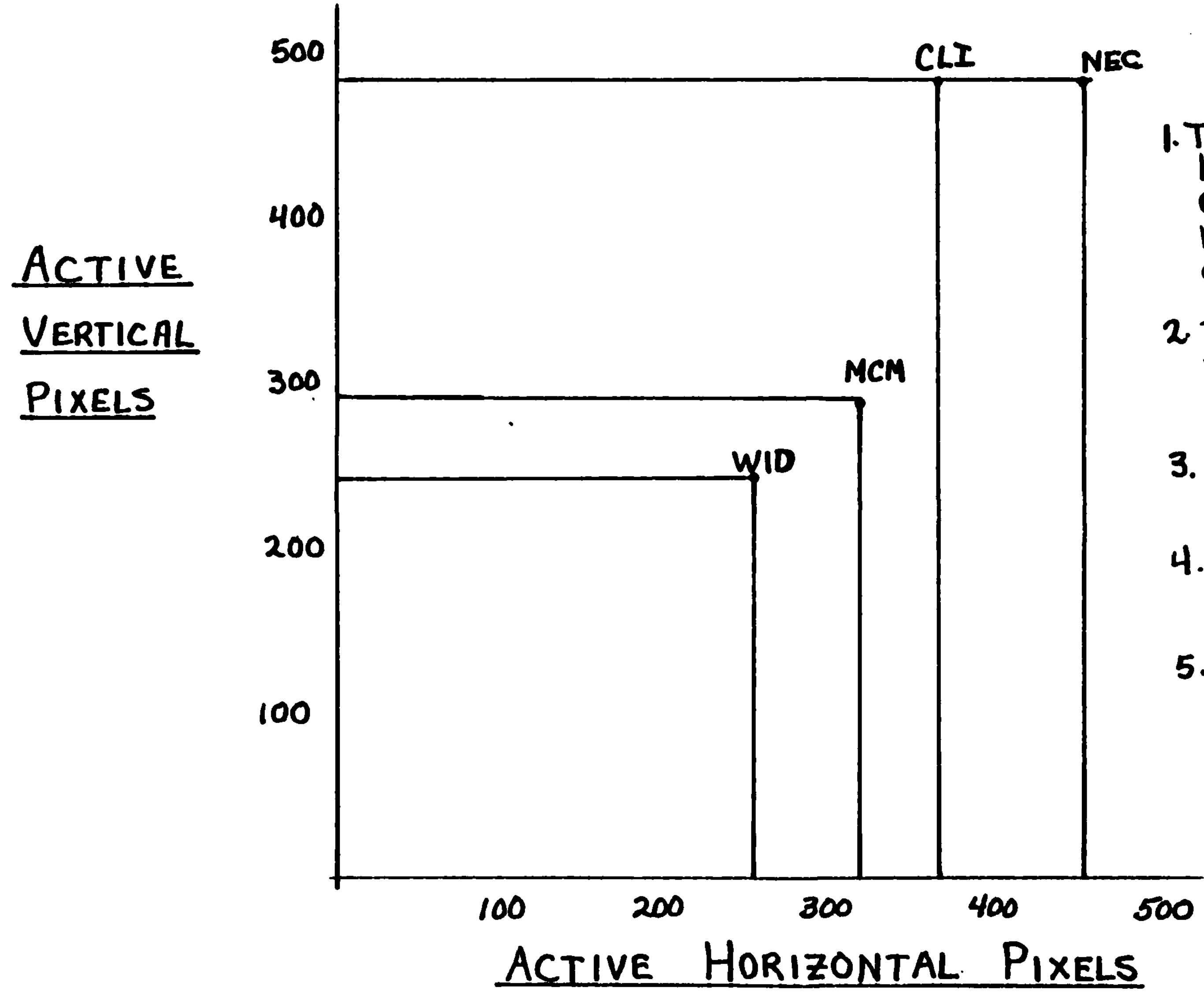
Parameter, Specification or Performance	Compression Labs	Nippon Electric	McMichael Ltd	Macom DCC	ATT PMS	Widcom
1. Codec name/model and transmission rate	VTS 1.5 / 1.5MBS	NETEC-X1 / 1.5 MBS	Video Conferencing / 2.0 MBS	NR	Netec / 1.5/3	VCU-2/56 / 256 KBS
2. Horizontal resolution	368 pixels	455 pixels	320 pixels	NR	NR	256 pixels
3. Vertical resolution	480 pixels	Assumed 480 pixels	286 pixels	NR	NR	240 pixels
4. Frame rate	15 frames per second constant	30 frames per sec. variable	25 frames variable	NR	NR	10 frames per second variable
5. High detail	368X 480 resolution	455X 480 resolution	575 X 320 resolution	NR	NR	256 x 240 resolution
6. Fast/high content motion sequences	constant 15 frame/ sec jerkiness	reduced horizontal vertical resolution, blurry trailing edges	reduced V + H resolution, trailing edges	NR	NR	Resolution and frame rate is reduced by motion content
7. Maximum no. of pixels/ frame	176,640	218,400	91,520/184,000	NR	NR	61,440

Note:

The MCM codec has a reduced frame rate mode of operation which provides 575 vertical pixels response for high detail static images. Figure 5.7.1 shows these results graphically where the area of the larger rectangles represent higher resolution images.

The NEC and MCM codecs normally operate at 30 and 25 frames per second respectively when the amount of motion content is minimal. As the motion content increases, then both codec algorithms act to reduce resolution of the displayed picture horizontally, vertically, and temporarily. This process can produce bluriness and trailing edges. In contrast, the CLI codec maintains a constant 15 frame/ second image during high motion content which can produce visible jerkiness.

FIGURE 5.7.1 COMPARISON OF TOTAL ACTIVE PIXELS TO REPRESENT AN IMAGE



NOTES

1. The rectangles bounded by lines to the left and below each name represent the relative resolution capability of each codec.
2. The NEC rectangle represents the potential to transmit the highest resolution image.
3. The NEC and CLI represent 1.544 MBS transmission.
4. The MCM represents 2.048 MBS transmission.
5. The WID represents 256 KBS transmission.

5.7.4 Codec Implementation Complexity Comparisons

The information provided in Table 5.7.3 provides insight into the complexities associated with each codec. For example, in the physical sizes provided by the vendors a volume was calculated for each codec which shows that the CLI codec is about twice the volume of the MCM codec while the NEC codec is about three times greater. For users who have space constraints, the codec size could be important. Also, the weight data is somewhat similar to volume data.

The power requirement is another indication of the electronic complexity of the codec. From the data supplied in Table 5.7.3, it is clear that the MCM codec uses less power than NEC (750 watts compared to 1200 watts) and apparently the CLI codec uses about twice as much power as the MCM. One could thus conclude the the MCM codec has probably considerably less circuitry than the other two codecs.

The operational environmental data in the Table 5.7.3 is provided for information purposes. For the codecs shown, all will operate under similar temperature ranges and relative humidity conditions.

Table 5.7.3 CODEC COMPLEXITY COMPARISONS

Complexity Characteristics	CLI	NEC	MCM	DCC	ATT	WID
1. Terminal Configuration	Duplex	Duplex	Duplex	NR	Duplex	Duplex
2. Model Number/Description	VTS 1.5 400188	NETEC-X1(MC) NPC-116B-M	European Exchange Version	NR	NETEC 1.5/3	VCU-2/56
3. Size:					NO RESPONSE	TBD
Height (inches)	51	83	NR	NR		
(CM)	130	NR	113.2	NR		
Width (inches)	25	23	NR	Mount in standard 19" rack		
(CM)	64	NR	51.3			
Depth (inches)	24	24	NR	NR		
(CM)	51	NR	45.1	NR		
Calculated Volume-inches^3	30,600	45,816	15,982	NA		
4. Weight (pounds)	400	NR	NR	NA		
(Kilograms)	180	250	75	NA		
5. Power Requirements:						
AC Voltage	115$\pm$10%	117$\pm$10%	110	NA		
Amperes	20 max	NR	NR	NA		
Watts	NR	1200 or less	less than 750	NA		
Hertz	60$\pm$10%	55 to 65	50/60	NA		
6. Operational Environmental Characteristics:						
Temperature (degrees F)	50 to 75	NR	NR	NR		
(degrees C)	10 to 20	10 to 40	10 to 30	10 to 40		
Relative Humidity (percent)	60 (non-condensing)	20 to 55	80 (non-condensing)	10 to 95 non-condensing		
Storage Temperatures (degrees F)	NR	NR	NR	NR		
(degrees C)	NR	-30 to 80	NR	-25 to 70		
Storage Relative Humidity (percent)	NR	up to 95	NR	0 to 99 non-condensing		
Operating Altitude Range (feet)	NR	0-12,000	NR	0-10,000		

5.7.5 Product Life

In Table 5.7.4 there are comparisons of various factors concerning the product life of the codec as provided by the codec vendors. The range of codec product life is listed from 4-5 years to 15 years with an average span of 8.5 years. Since there are no universal guide lines which dictate how to specify product life, the significance of this information is somewhat limited.

Of more importance is the announced improvements and modifications as shown in Table 5.7.4. For CLI and NEC the emphasis is placed primarily upon performance improvements including reduced bit rate transmission. Both vendors have publically announced that improvements will be demonstrated in the Spring of 1983. MCM plans include a demonstration of a 525 TV system at 1.5 MBS also in Spring 1983.

Another factor in Table 5.7.4 indicates there are several terminal configurations available - NEC has listed 20 terminal combinations.

TABLE 5.7.4 PRODUCT LIFE OF CODECS

	CLI	NEC	MCM	DCC	ATT	WID
1. Expected Product Life period of Codec	7 years	15 years	10 years		4-5 years	5-7 years
2. Planned Improvements/ Modifications	Reduced band-width and reduction in size of enclosure	Motion compensation is available now	LSI for cheaper cost. Coding will remain the same	No Response	No Response	Yes, (No detail provided)
3. Growth Potential	I/O slots available for future growth	N/A	Only codec with potential to be world standard			Yes (No detail)
4. Custom Configuration	Full duplex, R/O, S/O	20 models available	Exchange or Studio Version			Quoted on request
5. Additional Comments/ information on Product Life	NR	One failure reported during 40,000 hours operation	NR			None

Note: NEC lists motion compensation a planned improvement. However, all NEC data provided for this study is based upon a codec operating at 1.544 MBS with motion compensation.

5.7.6 Codec Pricing and Delivery

The data contained in Table 5.7.5 was supplied by the vendors specifically for this study - all prices were valid as of December 1982 for the models shown. It is advised that the pricing data shown in the table not be used for budgeting purposes because the prices may not be valid due to (1) discounts, (2) revised pricing schedules, or (3) optional features.

For comparison purposes, NEC and CLI (the only codecs field demonstrated at 525 lines and 1.5 MBS transmission rate) codecs including audio, and encryption features are priced at $153,000 and $152,500 respectively. This combination of features are probably typical of the motion codecs in operation or are being procurred. Thus, the price is a toss-up in the selection process according to this vendor supplied data.

The MCM codec is projected to sell at about two-thirds of the price of NEC and CLI. The other codec shown in the table is the WID codec which operates at much lower bit rates with reduced quality. Therefore, the WID price can not be compared with the other codecs at this time.

The delivery of codecs is listed between 5 and 7 months for CLI and NEC respectively, during 1983 for MCM, and no dates are available for DCC and WID.

Table 5.7.5 COMPARISON OF CODEC PRICES AND DELIVERY

	CLI	NEC	MCM	DCC	ATT	WID
1. Date of Pricing	Nov. 1982	Nov. 1982	Dec. 1982	NA	Dec. 1982	Dec. 1982
2. Basic Full Duplex Terminal	$151,000.	$134,000.	$90,000 to $100,000.	NA	FCC Tariff #271 until 12/31/82.	$135,000. (transceiver)
Model Number	VTS 1.5	(NPC-116B-M)	NR	NA	Detariffed after Jan1, 1983. New prices not available	
3. Options						
a. Audio Codec	$1,500.	$6,000.	NR			Optional, No price given
b. Encryption			$7,000.			NA
1. Audio	Standard	$7,000.				
2. Video	Standard	$6,000.				
c. Auto Diagnosis	Standard	$24,000.	NR			Optional, No price given
d. Still Frame Transmission	$16,500.	$8,000.	NR			
e. Forward Error Correction	Standard	Standard	$10,000 to $20,000			Optional, no price given
4. Stated Delivery	5 months	7 months	Available 1983	NA	NR	NA

It is quite apparent that the delivery dates are directly related to the state of development of each codec. Since CLI and NEC have units in the field, they have the shortest deliveries, while the other vendors are still in various development stages for their codec product.

5.8 Digital Interfaces and Specifications

5.8.1 Discussion of Interfaces

In this section, the comparison of motion codecs is made by studying their digital interfaces. Included in the comparisons are transmission channel bit rates, channel data formats, equipment data formats, and other digital data inputs and outputs to the codec. A brief discussion of the various types of interfaces and data formats associated with motion codecs is provided in the following subsections.

5.8.1.1 Transmission Channel Interfaces

The digital transmission channel interface is described as a specification usually associated with a hierarchy of digital channel transmissions. For the codecs in this study there are two specifications applicable to 1.544 MBS data rate—DS1 promulgated by American Telephone and Telegraph Company (References 5.1 and 5.2) and Recommendation G.733 adopted by the CCITT (Reference 5.3).

The two standards are very similar in many aspects; each has a frame size of 193 bits of which 1 bit is used for a framing signal. Also, the pattern for the framing bit is identical in both standards. It is beyond the scope of this study to compare the two specifications in more detail.

The MCM codec also has a transmission bit rate of 2.048 MBS which applies for TV systems operating at European 625 line TV standard. This transmission channel interface is specified by the CCITT Recommendation G.732 standard.

5.8.1.2 Data Channel Formats

The data channel format is described by requirements imposed upon the transmitted data bits. The 1.544 MBS T1 data channel is the primary data channel being used for video teleconferencing systems. It is also the primary transmission bit rate specified by most vendors of motion codecs.

The requirements imposed on the asynchronous T1 channel are contained in Bell System Technical Reference, Publication 41451 (Reference 5.4). The following signal format constraints are among the T1 requirements:

1. at least three pulses in any 24 bit intervals;
2. not more than 15 consecutive zeroes;
3. not more than 250 consecutive bit intervals of alternating ones and zeroes.

The T1 channel also specifies the electrical signal interfaces, type of connector, and pin assignments.

It is also possible to transmit the codec 1.544MBS bit rate synchronously to interface with a non-T1 data channel. In this case, some vendors have choosen

AD-A132 080 STUDY OF POTENTIAL STANDARDIZATION OF VIDEO TELECONFERENCING SYSTEMS VOLU..(U) DELTA INFORMATION SYSTEMS INC JENKINTOWN PA R V COTTON ET AL. MAY 83 2/2

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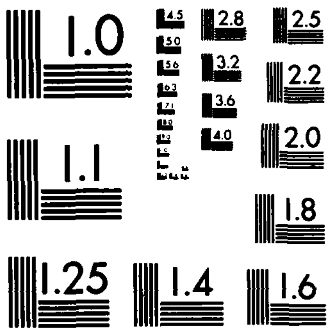


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

to meet EIA RS449 connector interface for data terminal equipments (Reference 5.5) and EIA RS422A electrical interface (Reference 5.6).

The carriers providing 1.544 MBS synchronous data services may attach further restrictions on the data format. However, no applicable standards are known at his time.

5.8.1.3 Equipment Data Formats

In addition to the requirements, specifications, and data formats described in the two previous sub-sections, each codec equipment has its own transmission data format or protocol. This format designates the assignment of the data bits. For example, bits may be assigned for equipment synchronization, framing, video, audio, other data, and forward error correction.

It is noticed that having standardized equipment data formats/protocols is fundamental to the standardization and interoperability process.

5.8.2 Transmission and Data Channel Comparisons

Table 5.8.1 contains the comparison of the major characteristics of the transmitted channel bit rate for each codec It is noted that all vendors provided responses at 1.544MBS transmission rate except the WID codec. Some of the codecs.

TABLE 5.8.1 Comparison of Digital Transmission and Data Channel Signals

Characteristic	CLI	NEC	ATT	MCM	DCC	WID
1. Codec Output Bit Rate	1.544MBS std 448KBS opt 2.048MBS opt	1.544MBS	1@1.544MBS or 2@1.544MBS	1.544MBS(US) 2.048MBS (Europe)	1.544MBS	256KBS to 56 KBS
2. Number of Outputs/ Inputs	1	1	1/2	1	NR	1
3. Digital Output Standard						
Asynchronous	DS1	DS1	DS1	G733(US)	NR	Not Available
Synchronous	RS449/422A	RS449/422A	Not Available	Optional	NR	Not specified
4. External Clock Requirements						
Asynchronous Transmission	No	No	No	No	NR	Not Available
Synchronous Transmission	Yes	Yes	Not Available	Yes	NR	Yes
5. Bit Rate/clock stability	1.544MBS ±50ppm	1.544MBS ±200ppm	1.544MBS Output ±50BPS Input ±200BPS	1.544MBS ±50ppm	NR	Bit rate will track input clock

have optional rates for lower rate transmissions, or compatibility with European communication channels, or for apparent better quality. Also, contained in Table 5.8.1 are the data channel formats specified by the codec vendors.

The CLI, NEC, and ATT codecs have adopted the DS1 transmission channel interface specification for 1.544 MBS bit rate. The MCM meets the G733 interface specification for 1.544MBS bit rate which is nearly identical with the DS1. Thus, all four vendors who have equipments in the field essentially meet a common transmission channel interface specification at 1.544MBS.

For synchronous transmission, CLI and NEC have adopted a common RS449 connector interface and RS422A electrical signal interface. MCM provides an optional synchronous output but no information on its characteristics was provided. The WID codec is specified for synchronous operation at all bit rates but no standards were listed.

Transmission bit rate/clock stability was similiar for all codecs operating at 1.544MBS. The codecs apparently meet the DS1 standard but there appears to be some disparity in the stability requirements among the previously referenced documents.

5.8.3 <u>Equipment Data Format Comparisons</u>

Each vendor was asked to provide detailed information about the composition of their codec transmitted bit stream.

Since each response was stated differently, the data contained in Table 5.8.2 has been derived from the vendor submissions and attempted to be normalized for comparison purposes. It should be recognized again that this information was provided in the fourth quarter of 1982 and is subject to changes in equipment enhancements.

The NEC and MCM codec bit streams have adopted an "equipment data format" based upon the DS1 and T1 framing formats; that is, their data frames are composed of 193 bits/frame and provide for 8000 frames per second. The CLI codec, although compatible with T1, uses a frame size of 4096 bits with 375 frames per second and an additional 8000 bits for the T1 frame signal.

There is room for interpretation in the number of data bits provided for customer use in the CLI and MCH codecs. CLI indicates that there is one 1200 BPS asynchronous port and two 9.6 KBS to 448 KBS data ports. The numbers used in Table 5.8.2 have assumed the 1200 BPS data port and two additional data ports 9600 BPS each.

Aside from the previous mentioned frame size commonality, there does not appear to be any similarity among the equipment data formats.

In order to obtain an overall view of the total bit allocations among the codecs, the data presented in Table 5.8.3 shows the total bit allocations for 1 second of transmission. The most significant items in the table are the video and audio allocations. The three codecs utilize very similar video bit

TABLE 5.8.2. Comparison of Codec Data Formats[1] for T1 Transmission

	CLI		NEC		MCM [3]	
1. Codec Frame Size	4096		193 Bits		193 Bits	
2. Frames/Sec	375 (1.536 MBS)[2]		8000 (1.544 MBS)		8000 (1.544 MBS)	
3. Video Bits/Frame	3690		167		160	
3A. Percent Video BITS		90.09%		86.53%		82.90%
4. Audio Bits/Frame	296		16		8	
4A. Percent Audio Bits		7.23%		8.29%		4.15%
5. Customer Data Bits	54		1		8	
5A. % Customer Data Bits		1.32%		0.52%		4.14%
6. Bits for T1 Compatibility	—		8		1	
6A. % Bits for T1 Compatibility		—		4.14%		0.52%
7. Other bits (Encryption, FEC, etc)	32		1		—	
7A. % Other bits		0.78%		0.52%		—
8. Synchronization, Control	24		—		16	
8A. % Synchronization, Control		0.58%		—		8.29%
TOTALS	4096	100.00%	193	100.00%	193	100.00%

NOTES

1. Numbers derived from documents submitted to DIS.
2. Add 8000 BPS to 1.536 MBS for T1 Framing for total of 1.544 MBS.
3. Numbers extrapolated from documents submitted by BTI and is subject to modifications.

TABLE 5.8.3 Comparison of Bit Allocations at 1.544 MBS Transmissions

	CLI BITS/SEC	NEC BITS/SEC	MCM BITS/SEC	Average BITS/SEC
1. Video	1,383,600	1,336,000	1,280,000	1,333,200
2. Audio	111,000	128,000	64,000	101,000
3. Customer Data	20,400[1]	8,000	64,000	30,800
4. Tl Compatibility	8,000	64,000	8,000	26,667
5. Control, synchronization, etc.	21,000	8,000	128,000	52,333
TOTALS	1,544,000	1,544,000	1,544,000	1,544,000

Notes

1. From vendor data sheets

   1 port @ 1200 BPS

   2 ports @ 9600 BPS (min.)

allocations with slightly more than 100,000 bits difference between the high and low codecs. Similarly, the audio allocation for the CLI and NEC codecs are close.

Items 3.-5. in Table 5.8.3 are not well explained and defined in some of the vendor responses and therefore there is uncertainty and room for interpretation. For instance, it seems reasonable to assume that if two external data ports at 448 KBS each are used in the CLI codec, then the performance of video portion of the codec would be seriously degraded.

5.8.4 British Telecom International Submission to CCITT

British Telecom (BT), developers of the European 2.048 MBS Codec manufactured by GEC-McMichael, Ltd (MCM), has made recommendations to the CCITT to have their codec compression algorithm be adopted as an international standard in Contribution 134. Further, a transmission standard has been proposed as described in Contribution 123. Table 5.8.4 lists the various proposed standards and formats for 2.048 MBS and 1.544 MBS transmissions. These proposed standards as provided by BT are contained in Appendix D.

It is noticed that some details have not yet been decided as indicated in both contributions 134 and 123 for 1.544 MBS transmission. It would thus appear premature to adopt these contributions as the international standard for codecs operating at 1.544 MBS. Further, there has been no public evaluation of the codec at 1.544 MBS - the performance of the codec at 2.048 MBS transmission is not necessarily valid at 1.544 MBS.

TABLE 5.8.4 BT Submission to CCITT

	2.048 MBS Transmission	1.544 MBS Transmission
1. Channel Hierarchy Standard	G732 32 channels @ 64KBS	G733 24 channels @ 64 KBS plus 8000 bits
2. Data Frame Format Standard	Contribution 123	Contribution 123
3. Codec Processing Standard	Contribution 134	Contribution 134
4. Applicable Television Standard	CCIR Rec. No. 624 (System M)	CCIR Rec. No. 472
Frame Rate	25 Frames/Sec	30 Frames/Sec
Line Rate	625 Lines/Frame	525 Lines/Frame

5.8.5 Summary of Digital Interface Data

In the previous subsections comparisons have been made of the various digital interfaces of the codecs. If codecs are to be compatible and interoperable from different vendors, then of course, the codec processing (compression) algorithms must be compatible. In addition, the three digital interfaces of the transmitted bit stream must be standardized - (1) equipment data interface, (2) data channel interface, and (3) the transmission channel interface.

Three of the codec vendors provide both asynchronous and synchronous transmission. All four vendors incorporate the asynchronous T1 data channel interface while there are no data channel standards for the synchronous transmission. But two vendors do meet the same connector and electrical signal interface, RS 449 and RS 422A.

NEC and MCM have incorporated the digital hierarchy of the DS1 and G733 transmission channel interface which are very similar at 1.544 MBS transmission. This format utilizes a 193 bit frame

In analyzing the assignment of bits allocated for video transmission, it is observed that CLI; NEC, and MCM use approximately the same number of bits (within 10%) and CLI and NEC also use approximately an equilvalent number of bits for audio transmission (within 14%).

Although a proposal has been made to the CCITT for establishing a codec and transmission data frame standard for video teleconferencing, it appears premature because all details of the standards have not been specified and the performance of the MCM codec operating at 1.544 MBS has not been observed nor compared with other codecs currently operating at 1.544 MBS. Considerable study and evaluation of the codecs is necessary using standard measurement techniques to make meaningful performance comparisons.

5.9 Bit Error Performance

5.9.1 Discussion

The bit error performance of motion codecs is significant as the overall performance of the codec could be greatly affected by the number of and the manner in which data link errors alter the compression algorithm preocessing in the receiving portion of the codec. It is generally well-known that as higher compression ratios are employed in codecs, the greater affect a bit error has upon the compression process.

In a one-dimensional TV compression technique such as delta modulation, a bit error can affect several or all the pixels in the same TV line. In a two-dimensional compression technique pixels in two or more TV lines could be affected by a bit error. In a inter-frame compression algorithm, a bit error could affect several pixels for several successive TV frames.

Codecs can employ forward error correction (FEC) coding which provides for the detection and correction of data link bit errors. There are several methods and degrees of error correction which can be incorporated in the codec. FEC, however, does require that additional transmission bits be assigned for this purpose which in effect reduces the overall compression efficiency of the codec.

Bit errors generally occur in random fashion on data links. Usually on transmission channels used for video conferencing such as satellites successive bit errors can occur due to burst-type noise effects. Thus, some codecs provide FEC which will correct single error bursts up to 9 bits in length.

In the vendor questionnaire, several subjective questions and visual effects were asked about the codec operating in various bit error conditions. No objective measurements were specified in the questionnaire due to the lack of having standardized motion video inputs, standardized techniques for contaminating the transmitted bit stream, and standardized measurement techniques to apply to the decoded TV picture. Thus, the results presented in the following sub-sections represent the vendors answers to the questions.

5.9.2 Subjective Measurements

The questions asked about the codecs were limited to subjective evaluations as noticed in observing the quality and effects of bit errors in the codec output picture. A basic observation was to determine if the errors were perceptible at each of four bit error rates. If errors are perceptible, then the type of effect was to be described such as blocks, streaks, flashing lines, color changes, etc.

Another question related to ability of the codec receiver to maintain synchronization of the TV image including horizontal, vertical, audio, etc. Finally, the effect of bit errors upon the encrypting/decrypting process, if employed in the codec, was to be specified. This could be important because an error in an encrypted signal could be multiplied into several errors due to the encryption process.

5.9.3 Comparison of Bit Error Performances

Tables 5.9.1 through 5.9.4 contain the comparisons of the various codecs under bit error rates ranging from 10^{-6} to 10^{-3}. An important consideration in comparing the performance of motion codecs under varying bit error rate conditions is whether the codec has either a built-in or optional Forward Error Correction (FEC) subsystem. In the codecs listed in Tables 5.9.1-5.9.4, CLI and NEC have built-in FEC circuitry and MCM indicates FEC as optional but required if the BER is worse than 10^{-6}. The WID responses are based on no FEC which is available as an option.

For a BER of 10^{-6}, Table 5.9.1, the CLI, NEC, and MCM codec report no perceptible visual degradations due to errors. However, WID indicates that perceptible blocking errors will occur and that the receiver could lose synchronization. When the BER is 10^{-5}, Table 5.9.2, both CLI and MCM indicate that the errors are perceptible and can be manifested as error data blocks and as small "comet tail" streaks. NEC also indicates that streaks may occur. Also at this BER, MCM reports that an error could affect a "single encryption block" if no error correction is utilized.

Table 5.9.1 Bit Error Performance at BER 10^{-6}

NP-No Response
CP-Company Proprietary
NA-Not Available
TBD-To Be Determined

Parameter, Specification or Performance	Compression Labs	Nippon Electric	McMichael Ltd	Macom DCC	ATT PMS	WIDCOM
1. Are errors perceptible?	No	Not Perceptible	No with error correction, Yes without correction	No	NR	Yes
2. Describe visual effects of errors-Blocks, lines, streaks, color changes, etc.	-	-	Small "Comet tail" streaks	-	NR	Blocks
3. Does receiver maintain complete synchronization (i.e. vertical, line, audio, etc)?	Yes	Yes it does	Yes	Yes	NR	No-can lose sync
4. If scrambling/encryption system is supplied, is scrambling/decryption affected?	No	No effect	No	NA	NR	Optional
5. Incorporates built-in Forward Error Correction (FEC).	Yes	Yes	Optional - required for BER worse than 10^{-6}.	NR	NR	No. Option is available.

Table 5.9.2 Bit Error Performance at BER 10^{-5}.

Parameter, Specification or Performance	Compression Labs	Nippon Electric	McMichael Ltd.	Macom DCC	ATT PMS	Widcom
1. Are errors perceptible?[2]	Yes	Not Perceptible	Yes	NA	NR	Yes
2. Describe Visual effects of errors-blocks, lines, streaks, color changes, etc.	Occasional black artifacts	May perceive streaks	small "comet tail" streaks	NA	NR	Blocks
3. Does receiver maintain complete synchronization (i.e. vertical, line, audio, etc.)[2]	Yes	Yes it does	Yes	Yes	NR	No
4. If scrambling/encryption system is supplied, is scrambling/decrypting affected?	No	No effect	Could cause error in a single encryption block if no error correction option	NA	NR	NA

COMPARISON OF MOTION CODECS

TABLE 5.9.3 Bit Error Performance at BER 10^{-4}

Parameter, Specification, of Performance	Compression Labs	Nippon Electric	McMichael Ltd.	Macom DCC	ATT PMS	Widcom
1. Are errors perceptible?	Yes	May perceive errors	Yes	NA	NR	Yes
2. Describe visual effects of errors-blocks, lines, streaks, color changes, etc.	Impairment significant	May perceive streaks	Streaks and print errors Unacceptable for long periods without error correction	NA	NR	Blocks
3. Does receiver maintain complete synchronization (i.e. vertical, line, audio, etc)?	No	Yes it does	Yes	NA	NR	No
4. If scrambling/encryption system is supplied, is scrambling/decrypting affected?	No	No effect	Could cause error in a single encryption block if no error correction option	NA	NR	NA

TABLE 5.9.4 Bit Error Performance at BER 10^{-3}

Parameter, Specification, or Performance	Compression Labs	Nippon Electric	McMichael Ltd.	Macom DCC	ATT PMS	Widcom
1. Are errors perceptible?	Yes	May perceive errors	Yes	NA	NR	Yes
2. Describe visual effects of errors-blocks, lines, streaks, color changes, etc.	major impairment	May perceive streaks	Complete picture breakup	NA	NR	Blocks
3. Does receiver maintain complete synchronization (i.e. Vertical, line, audio, etc)?	No	Yes it does	No	NA	NR	No
4. If scrambling/encryption system is supplied, is scrambling/decryption affected?	No	No effect	Yes-unuseable. Error correction option will not help at this BER.	NA	NR	NA

At 10^{-4} BER, Table 5.9.3, the performance of the codecs takes a sharp reduction. All vendors indicate the errors are perceptible and for the most part the performance of the codec would probably be unsatisfactory. CLI reports that their receiver would not keep in synchronization.

For operation at 10^{-3} BER, Table 5.9.4, apparently none of the codecs will operate satisfactorily for teleconferencing applications.

5.9.4 Forward Error Correction

As mentioned earlier in this Section 5.9, codecs may employ Forward Error Correction (FEC) coding to provide protection from transmission errors which could cause a codec receiver to be out-of-synchronism with its corresponding codec transmitter. The effect of this out-of-synchronism could cause visible errors in the displayed image. Codecs employing multi-dimensional compression algorithms which yield high compression ratios are generally more susceptible to transmission errors than codecs employing one or two dimensional compression algorithms.

Table 5.9.5 contains a summary of FEC coding as provided by the codec vendors. Of the three vendors who provided FEC information, all three use Bose-Chandhui-Hocquenghm (BCH) coding algorithms. Each codec utilizes a different number of FEC correction bits; however, the CLI and MCH have nearly the same size FEC block size, 4096 bits and 4095 bits respectively. The NEC codec has a block size of only 225 bits.

Table 5.9.5 Forward Error Correction Coding

Parameter, Specification or Performance	Compression Labs	Nippon Electric	McMichael Ltd	Macom DCC	ATT PMS	Widcom
1. Type Code	BCH	BCH	BCH	NR	NR	Optional
2. FEC Block Size	4096	255	4095	NR	NR	NR
3. Correction Bits per Block	32	16	60	NR	NR	NR
4. FEC Correction Capability	Single burst of 9 bits	Single, double errors	5 isolated errors. Single burst of 26 bits	NR	NR	NR
5. FEC Redundancy (Percentage of Block) Size	0.8%	6.3%	1.5%	NR	NR	NR

The table further shows the types of errors which are claimed to be corrected for each of the FEC coding algorithms. No detail was provided by the vendors as to the actual BCH code used; therefore, no comment is offered as to the merits of each FEC code.

The FEC redundancy percentage was calculated and is provided for each codec as shown in the table. It is noted that CLI has 0.8% redundancy, while MCM has almost double with 1.5% redundancy. NEC, with 6.3% redundancy, has four times more redundancy as MCM. The adequacy of these redundancies is not known.

5.9.5 Summary of Bit Error Performance

In reviewing the codec performance data supplied by the vendors for various BER's as ahown in Tables 5.9.1 through 5.9.4, it is concluded that all codecs operating at 1.544 MBS (CLI, NEC, MCM) will perform very satisfactorily at 10^{-6} BER. This performance starts to degrade at 10^{-5} when error streaks or blocks may be perceptible. Without further testing and evaluation, it is unknown if operation at 10^{-5} would be satisfactory for teleconferencing use.

At 10^{-4} and 10^{-3} BER, the performance of all codecs appears to be sufficiently degraded so that they would be unsatisfactory for teleconferencing use.

It is again noted that the above comments assume that FEC is incorporated in the codec as shown in Table 5.9.5.

Section 5.0 References

5.1 "Video Teleconferencing Service Network Interface Specifications", July 1981, Technical Reference Publication 61511, American Telephone and Telegraph Company.

5.2 "Interconnection Specifications for Digital Cross-Connects", Technical Advisory No.34, Issue3, Oct. 1979, Attachment Item 40-68.

5.3 "Characteristics of Primary PCM Multiplex Equipment Operating at 1544 KBit/s", Fascicle III.3-Recommendation G.733, CClTT, Geneva 1972; amended at Geneva, 1976 and 1980.

5.4 "1.544MBS Digital Service", Technical Reference, Publication 41451, May 1977, American Telephone and Telegraph Company.

5.5 EIA Standard RS449-1,"General Purpose 37/9 Position Interface for Data Terminal Equipment and Data Circuit-Terminating Equipment", Feb. 1980.

5.6 EIA Standard RS 422A "Electrical Characteristics of Balanced Voltage Digital Interface Circuits", Dec. 1978.

5.7 "Quantization Effects on Differential Phase and Gain Measurements", SMPTE Journal, November 1982. Frederick A. Williams and Richard K. Olsen.

6.0 Communication Analysis - Task 3

6.1 Discussion

The purpose of this task is to conduct a brief investigation of the types of communications that are being utilized for digital video motion teleconferencing systems. In particular, the communications currently being used for the motion digital teleconferencing systems described in Table 4.5.1, Section 4 will be explored. In order to provide an overview of the utilization of motion codecs, Table 6.1.1, shows some typical applications, associated bit rates, type of communication channel, and compression techniques. The primary effort in this overall motion codec study has been concentrated on "long haul teleconferencing" applications - those systems operating at 1.5-3.0 MBS bit rates. However, codecs and systems operating at other bit rates have been considered.

The remainder of Section 6 outlines the various communication types for specific video teleconferencing systems including point to point systems as well as switched point to point networks. Tariffs, protocols, and other bit rates are also characterized.

Table 6.1.1 Typical Motion Codec Applications and Bit Rates

Typical Application	Coding Technique	Typical Bit Rate	Typical Communication Channel
1. Digital Studio Processing	PCM (No Compression)	Equilvalent to 100MBS	None
2. Digital Broadcast	Intraframe	45 MBS	Satellite Transponder
3. Local Teleconferencing	Inter and Intraframe	3.1 MBS to 40.0 MBS	Microwave, Fiber Optics
4. Long Haul Teleconferencing	Inter and Intraframe	3.1 MBS 1.5 MBS USA 2.1 MBS Europe	T-1 Terrestial and Satellite
5. Reduced Quality Teleconferencing	Inter and Intraframe Reduced Resolutions	56 KBS to 1.0 MBS	Satellite
		56 KBS	Switched Data Network

6.2 Communications for Existing Motion Codec Systems

This subsection is a compilation of most of the known digital motion video teleconferencing systems and the communications used. Distribution arrangements for teleconferencing can be classified as shown in Table 6.2.1. Of the systems in existance today, the only known types being used are those in Catagories 1 and 2, defined in the table as point to point. In Ad Hoc Teleconferencing (known sometimes as impromtu teleconferencing) many point to multipoint video conferences have been conducted generally for special purpose events. These conferences use full motion and full analog bandwidth television channels, do not use codecs, and are not usually conducted in permanent rooms or locations. Analog video teleconferencing has not been considered in this study.

6.2.1 Two Node Point to Point Systems

Table 6.2.2 provides a summary of existing digital video teleconferencing systems with their communications. The two US Army systems provide high quality digital video which require a bit rate of 36.8 MBS. These dedicated microwave communication links are special purpose tailored to meet the video transmission bit rate and are not generally available as a tarrifed communication service.

Table 6.2.1 Distribution Arrangements for Video Teleconferencing

Catagory	Type of Video Conference	Description
1.	Point to Point	Two remote locations or nodes are connected together in a 2-way conference. The connection can be dedicated for full-time use or patched together when needed.
2.	Point to Point (Switched Network)	Three or more remote locations or nodes are formed together into a network where any one location can be connected (switched) to any other one location at a given time in a 2-way conference. More than one point to point conference can exist at a given time.
3.	Point to Multipoint	Three or more remote locations or nodes are formed together into a network where one location can transmit to two or more other locations in a broadcast only mode. This connection can be dedicated or switched.
4.	Multipoint to Multipoint	Three or more remote locations or nodes are formed together into a network where one location can transmit and receive a video conference from twc or more other locations simultaneously. This connection can be dedicated or switched and generally requires more than 1 set of communication links to each location.

Table 6.2.2 Point to Point Communications for Motion Video Teleconferencing Systems

User/Owner Organization	System Locations	Digital Video Transmission Bit Rates	Communication Carrier	Type of Link	Comments
1. US Army	Washington,DC	36.8 MBS	Western Union	Microwave	Link transmits other data. Total BR=45MBS
2. US Army	Washington,DC	36.8 MBS	Western Union	Microwave	Link transmits other data. Total BR=40 MBS
3. NASA	Washington, Houston	1.5 MBS	Radio Corporation of America	Satellite	
4. Allstate Insurance	Chicago, Menlo Park,CA	1.5 MBS	Satellite Business System	Satellite	System is planned to expand to 28 locations.
5. Aetna Insurance	Hartford, Chicago	3.0 MBS	Satellite Business System	Satellite	Transmits 2 separate digital 1.5 MBS video signals. Expected to expand to additional nodes.
6. America Bell, Inc. and British Telecommunications International	New York City London, England	1.5 MBS	American Telephone and Telegraph Co., British Telecommunications International	TAT-6 Submarine cable and land cable	Trial System

The NASA and Allstate systems operate at 1.5 MBS utilizing T1 satellite transmission and CLI and NEC codecs respectively. The Aetna system is currently using two T1 channels to simultaneously transmit 2 motion codec signals. All of the above nodes generally have on-premise earth stations to directly access the satellite.

An experimental international video teleconferencing system is being tested between the AT&T's New York Picturephone Meeting Service public room and British Telecom's London Confravision studio. The cross ocean communication is TAT-6 analog submarine cable which has been configured to provide a duplex 1.544 MBS circuit. Terrestial communications at each end of the submarine cable provide the communications to the user locations. There is no tariff because of the experimental nature of the test. Figure 6.2.1 is a diagram of the international communications for this experimental motion codec test.

6.2.2 Network Systems

Some of the video teleconferencing systems which have more than 2 nodes or locations are shown in Table 6.2.3. Although there are several nodes in each network, there are no known systems which

FIGURE 6.2.1. INTERNATIONAL MOTION VIDEO TELECONFERENCING COMMUNICATIONS

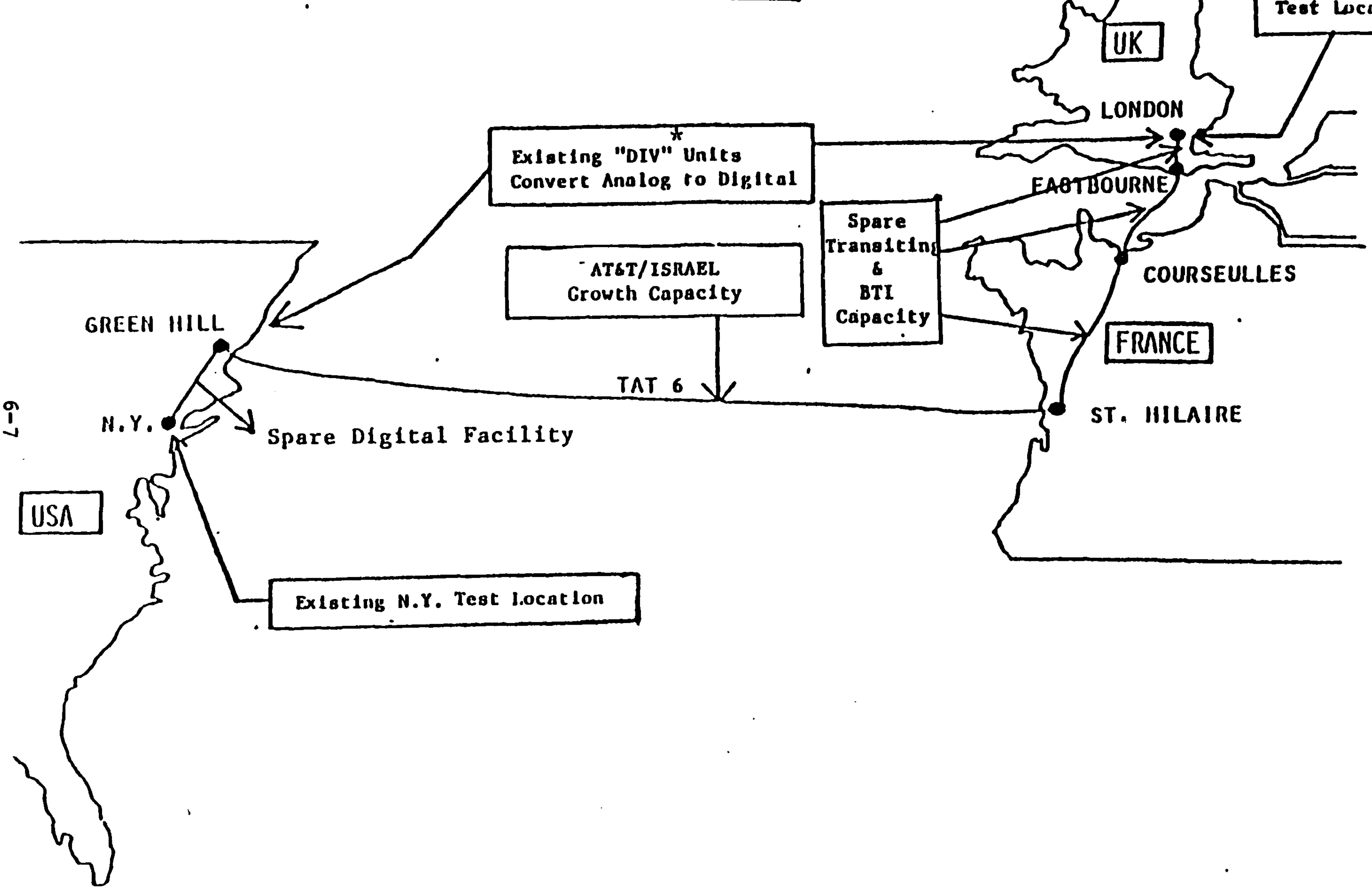


TABLE 6.2.3 Switched Network Communications for Motion Video Teleconferencing Systems

	Network Name/ Owner	Number of Locations/ Cities	Digital Video Transmission Bit Rate	Communication Carrier	Type of Link	Comments
1.	Picture Meeting Service. American Bell, Inc.	12 cities	3.1 MBS (2T1 lines)	American Telephone and Telegraph	Mixed Terrestial (Cable, Microwave & Satellite	Filed with FCC for reduced bit rate to 1.54MBS. Switched point to point.
2.	Shared Teleconferencing Network• ISA Communications	6 cities	1.5 MBS	Satellite Business Systems	Satellite	American General Insurance owns 4 locations. Switched point to point.
3.	Atlantic Richfield	3 cities	1.5 MBS	Western Union	Satellite	Switched point to point. Third city not operational.

provide multi-node teleconferencing - that is, simultaneous teleconferencing between more than two nodes at a time. Thus, in these networks, point to point conferences are established by switching and connecting the nodes through the communications system. It is clear, however, that the problems of multi-node interactive digital conferencing must be resolved as the need and desire for multi-point conferences increases with expanding networks.

As shown in Table 6.2.2., all multi-node networks use satellite communications which of course is natural because all locations (nodes) have equidistant access to the link. It is easy to add or remove nodes from the network merely by adding or removing earth stations. For the ATT PMS service, since some terrestial links are also used, changing the number of locations/nodes may be more complicated.

6.3 Motion Video Teleconferencing Tariffs

All common carriers and resale carriers who offer communications for digital motion video teleconferencing systems file tariff applications with the Federal Communications Commission (FCC) which acts to approve or disapprove the proposed service. There are many carriers today who are offering video conferencing services and communications. Further, these offerings before the FCC are constantly being changed and other new services being added at a rapid rate.

It is not the intent of this communication analysis nor of the entire codec study to provide information or details concerning all of these offerings before the FCC. However, in order to provide insight into the communications being utilized for video teleconferencing, some detail is provided on the current tariffs offered by AT&T for digital video conferencing. Also, for the readers information a description of the SBS digital communications offerings is provided.

6.3.1 AT&T Tariffs for Teleconferencing

AT&T is one of the leading common carriers which is offering digital communications for motion video teleconferencing systems. Table 6.3.1 contains a summary of the current (March 1983) AT&T tariffs being offered. Some earlier approved tariffs expired for video conferencing communications and terminal equipments on January 1, 1983 when AT&T was divided into American Bell Inc. (ABI) for unregulated services and AT&T Long Lines for

Table 6.3.1 Examples of Current AT&T Video Conferencing Tariffs

Tariff	Name of Service	Effective Date	Usage	Media	Bit Rates	Notes
270	High Capacity Terrestial Digital Service (HCTDS)	March 17, 1983	Dedicated	Terrestial	1.544 MBS	Dedicated connection from customer's premises to AT&T node.
273	High Speed Switched Digital Service (HSSDS)	July 2, 1982	Switched	Satellite, Terrestial	Dual 1.544 MBS channels	Basic service for video teleconferencing. Used to provide communications between nodes in the AT&T network.
273	High Speed Switched Digital Service (HSSDS)	Not Approved	Switched	Satellits, Terrestial	1.544 MBS	AT&T is filing for a single 1.544 MBS channel by June 1983.
267	Dataphone Digital Service (DDS)	Unknown	Dedicated	Terrestial	2400 BPS to 56 KBS	No longer used for motion video teleconferencing after Jan. 1, 1983. Previously offered 1.544 MBS service.
271	Terminal Equipments for Video Teleconferencing	Expired January 1. 1983	Dedicated	-	-	Tariff was for use of video teleconferencing terminal equipment at user's premises. This use is now unregulated offered by ABI.

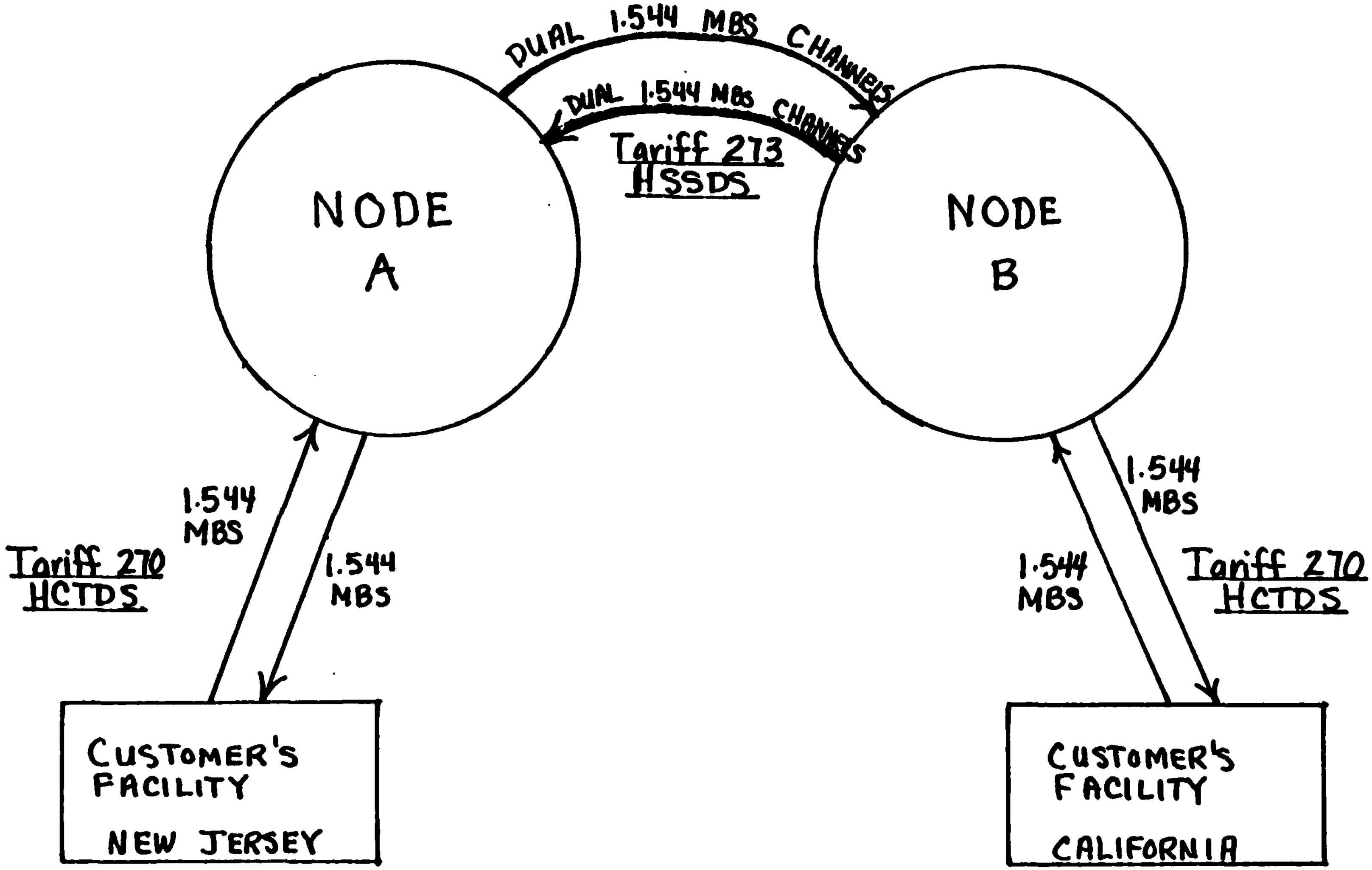
regulated communication services. For example, Tariff 271, which covered the lease costs of motion codecs, expired on January 1, 1983 and ABI now provides this unregulated service.

Tariff 270, High Capacity Terrestial Digital Service, (HCTDS) covers the costs of providing 1.544 MBS digital communications from the customer/users facility to the AT&T communications node. This tariff is for a dedicated (24-hour) terrestial link. The motion codecs compared in this study which operate at 1.544 MBS bit rate can interface to this service.

The second tariff currently offered by AT&T is Tariff 273, High Speed Switched Digital Service (HSSDS), which provides the "backbone or long haul" digital communications between AT&T nodes located at key places throughout the United States. This switched (non-dedicated) digital service presently uses two 1.544 MBS channels in each direction between nodes.

An illustration of how the two tariffs apply to a motion video teleconferencing system between New Jersey and California is depicted in Figure 6.3.1. Tariff 270 covers the cost of providing the local communications link between the customers faciltiy to the nearest AT&T node at both ends. Then Tariff 273 covers the cost of the communications between nodes only for the time actually used in the conference. Currently, this cost is for

FIGURE 6.3.1 ILLUSTRATION OF AT&T TARIFFS FOR MOTION VIDEO TELECONFENCING



3.0 MBS, but AT&T is anticipating to file for modification of Tariff 273 to provide only 1.544 MBS service.

6.3.2 SBS Communications Network Service

This section along with Appendix E provides some detail of digital satellite communications being offered for motion video teleconferencing systems by Satellite Business Systems (SBS). These offerings by SBS are generally by satellite where earth stations are located on or near customers premises. This is contrasted to the AT&T offerings which are generally terrestial communications sometimes in combination with satellite transmission.

The Communications Network Service (CNS) is a switched network service which is proposed to meet the intercity telecommunications requirements of large and medium-sized users. The CNS service is offered in two series. CNS-A is for customers who have the larger volume bit rate requirements and generally earth stations are located on the customers premises. CNS-B is a shared network service for lesser volume bit rate customers. An earth station may be shared by many customers who are connected to the earth station by terrestial links from their facilities.

Of importance to this study is that both CNS-A and CNS-B offer 1.544 MBS and 3.088 MBS digital communications as switched or non-switched services. In order to provide further information and detail on the kinds of digital communications available for video teleconferencing, a description of the SBS CNS service is contained in Appendix E.

6.3.3 Summary of Tariffs

The previous sections have briefly outlined some of the available common carrier tariffs available for motion video codecs. It is further emphasized that there are several other common carriers and many resale carriers who offer video teleconferencing communication services. A common thread which appears in nearly all offerings is a 1.544 MBS/ T1 service available for the motion codecs compared in this study.

These communication services are comprised of satellite and terrestial transmissions including microwave, fiber optic, and cable links. Point to point dedicated and switched service is offered.

6.4 Communications Interfaces and Protocols

In Section 5.8 digital interfaces and specifications were compared for the various codecs under study. It was found that there are generally at least three protocol formats and interfaces associated with a video teleconferencing system including the equipment data format, the data channel format, and the transmission channel format. In this section, a brief description of the types of data channel and transmission channel formats (where different) currently being used in existing video teleconferencing communication links will be provided.

Generally, the communication interfaces and formats require either asynchronous or synchronous operation from the motion codec. In synchronous operation, the data channel/communication link provides a clock to the codec which is used by the codec to provide output data bits in synchronism with the input clock. For asynchronous operation the terminal device (motion codec) provides a bit stream and clock to the data channel at the rate specified by the channel. These two types of operation will be described further in the following subsections which discuss briefly the AT&T T1 asynchronous communications and the SBS synchronous CNS communications.

As mentioned previously there are several common carriers offering terrestial and/or satellite high bit rate communications for video conferencing. There are some different interface requirements among the carriers. Also, the resale carriers which buy transmission capacity from the common carriers may impose additional bit pattern and framing restrictions upon the terminal equipments. However, it is felt that the two following examples will typify the data channel and transmission channel interface requirements.

6.4.1 AT&T T1 Communications

In several Technical Reference documents, AT&T describes the technical interface and protocol required to connect terminal equipments to the 1.544 MBS T1 video teleconferencing networks offered by AT&T as currently specified in Tariffs 270 and 273. The physical and electrical interface specifications are contained in AT&T Publication 61511, Reference 5.1. A detailed description of the 1.544 MBS channel service, frame protocol, and signal constraints is contained in AT&T Publication 41451, Reference 5.4.

The 1.544 MBS T1 channel can be used in both an asynchronous mode where the effective data rate is approximately 1.536 MBS or in a synchronous mode where the effective data rate is 1.344 MBS. In the asynchronous mode, certain restrictions are placed upon the bit patterns presented to the T1 data channel as part of the DS1 communications hierarchy. For every 192 information bits, there must be provided 1 framing bit which varies according to the following pattern.

1 0 0 0 1 1 0 1 1 1 0 0

Also, the following pulse density constraints are placed upon the transmitted bits from the terminal equipment which is connected to the 1.544 data channel:

1. At least three pulses in any 24 bit intervals.
2. Not more than 15 consecutive zeroes.
3. Not more than 250 consecutive bit intervals of dotting (alternating ones and zeroes).

There is also a synchronous mode available in the 1.544 MBS video teleconferencing service at a reduced information bit rate of 1.344 MBS. In this mode there are no waveform or pattern constraints and restrictions placed upon the bit stream received from the terminal equipment; however, there is a loss of nearly 200,000 bits which could be used for information. For this type of service, a 306-type Data Set must be used at each end between the terminal equipment and the 1.544 MBS data channel. In effect, the 306 Data Set provides the digital processing required to meet the above listed constraints for a 1.544 MBS T1 channel operating in the asynchronous mode.

The potential information rates of the 1.544 MBS data channel operating in its various modes are summarized in Table 6.4.1. It is clear that more efficient information transmission is realized when operating in the asynchronous mode (99.48% compared to 87.05% for synchronous T1 mode). Of course this efficiency is particularly important for motion codecs because of

Table 6.4.1 1.544 MBS Tl Transmission Channel

Mode	Transmitted Bit Rate	Framing/ Housekeeping Bits/Second	Effective Bit Rate	Effective BR/Transmitted in Per Cent
1. Asynchronous	1.544 MBS	8000*	1.536 MBS	99.48%
2. Synchronous	1.544 MBS	200,000	1.344 MBS	87.05%

* Additional bits may have to be designated for this function by the terminal equipment to meet the pulse density constraints of the 1.544 MBS Tl channel which would reduce the transmission efficiency.

the extremely high video compression ratios which must be achieved by the codec in order to operate at such a low 1.544 MBS bit rate. In other words, if the efficiency is increased (more information bits at a given bit rate), then the performance or quality of the resultant picture from the codec should increase.

6.4.2 SBS CSN Communications

In the SBS filing to the FCC, dated June 11, 1980, entitled "Communications Network Service Section 61.38 Information" information is provided specifying the interface requirements for the various digital bit rates offered in the CSN. Part of this filing is contained in Appendix E of this report.

The CSN provides synchronous switched and non-switched digital connections at various bit rates for both CSN-A and CSN-B customers. The interface requirements for some bit rates which may be used for video teleconferencing are shown in Table 6.4.2. The interface specified for the primary bit rates of interest is EIA Standard, RS 449, "General Purpose 37-Posiiton and 9-Position Interface for Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange", Reference 5.5.

Some of the important characteristics of RS 449 Standard applicable to the transmission of motion codec

Table 6.4.2 CSN INTERFACE REQUIREMENTS

Designated Service Type	Transmission Bit Rate	Transmission Mode	Interface Requirements
1. D1-448	448 KBS	Synchronous	RS-449, CCITT V.35 or 306-Type
2. D1-1344	1.344 MBS	Synchronous	RS-449, CCITT V.35 or 306-Type
3. D1-1544	1.544 MBS	Synchronous	RS-449, CCITT V.35 or 306-Type
4. D1-3088	3.088 MBS	Nonsynchronous	RS-449, CCITT V.35 or 306-Type

signals are listed below:

1. Applicable at data bit rates up to 2.0 MBS.
2. No restrictions are placed upon the arrangement of the sequence of bits provided by the motion codec.
3. Standard applies to both synchronous and nonsynchronous digital communication systems.
4. Standard is applicable to all classes of data communication service including switched, non-switched, dedicated, leased, two-wire, four-wire.

It is quite apparent that there is considerable more flexibility in the RS 449 interface than is in the 1.544 MBS T1 interface described in Section 6.4.1. It would appear that RS 449 is broad enough such that the data format and interface requirements of T1 could be directly transmitted on a RS 449 data circuit. This being the case, then the codec vendor can supply two physical outputs - one for RS 449 and one for T1 - with only one data (T1) format or protocol. In this way then the codec can interface with either the AT&T or SBS communication facilities or other carriers which exhibit the same interfaces.

In reviewing the interfaces specified by the codec vendors in Table 5.8.1, the CLI and NEC codecs both provide T1/DS1 and RS 449 interfaces.

6.5 Transmission Bit Rate

Some of the AT&T and SBS data rates available for video conferencing transmission were presented in Sections 6.3 and 6.4. For motion video teleconferencing the most common rates currently being used are single and dual 1.544 MBS data transmission channels. Referring to Table 6.5.1, it is noted that the primary transmission rate for 5 of the 6 codec vendors is 1.544 MBS.

However, the codec vendors do offer other transmission rates shown in Table 6.5.1. Both CLI and NEC have recently announced that modifications to their codecs will permit satisfactory operation at a lower bit rate of 750 KBS. Also, the WID codec was developed primarily to operate at bit rates significantly lower than 1.544 MBS. In the higher transmission rates the NEC codec will operate at 3.08 MBS and with modification at 6.3 and 12.9MBS.

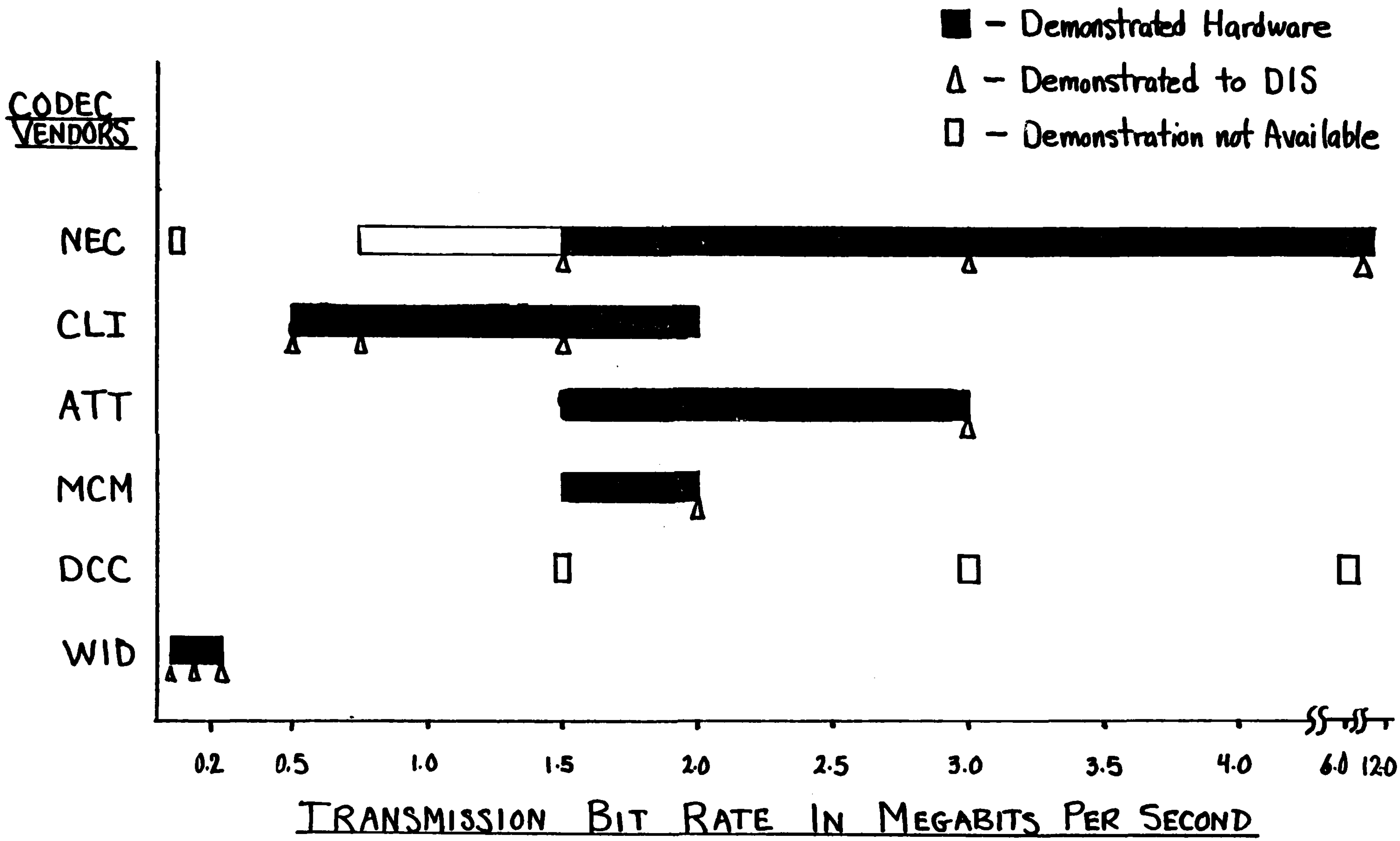
Thus, a wide range of bit rates can be employed for transmitting digital motion video teleconferencing signals. Figure 6.5.1 shows pictorially the announced transmission rates of motion codecs known to be available commercially or are in development for video teleconferencing systems. It can be seen that there are codecs readily available for teleconferencing applications ranging from bit rates of 500KBS to 6.3MBS. Codecs are being developed to operate below 100KBS and above 6.3KBS.

Table 6.5.1 Motion Codec Transmission Rates

Codec Vendor	Model Number	Transmision Rates 56/64 KBS	112/128 KBS	224/256 KBS	448 KBS	750 KBS	1.5 MBS	2.0 MBS	3.1 MBS	6.3 MBS	12.9 MBS	22.0 MBS
1. Compression Labs (CLI)	VTS 1.5				OPT	OPT	X	OPT				
2. Nippon Electric (NEC)	1. NETEC-X1(MC)					OPT	X		X	OPT		
	2. NETEC-X1.5/3					OPT	X		X	OPT	OPT	OPT
	3. Unknown	DEV										
3. McMichael Ltd. (MCM)	Video Conferencing						X	X				
4. MACOM Digital (DCC) Communications Co.	unknown						DEV		DEV	DEV	DEV	
5. American Bell, Inc. (ATT)	NETEC 1.5/3						X		X			
6. Widergren Communications (WID)	VCU-2/56	X	X	X								

NOTE: DEV - indicates codec in development.

FIGURE 6.5.1 ANNOUNCED CODEC TRANSMISSION BIT RATES.



6.6 Summary

Most of the video teleconferencing systems and networks currently in operation which use motion codecs are using 1.544 MBS transmission channels. The exception is the AT&T/ABI PMS service which currently uses two 1.544 MBS channels; however AT&T has filed for a tariff to operate with a single 1.544 MBS channel. It thus appears that the present and immediate future communications for most video teleconferencing applications will be at a 1.544 MBS transmission rate.

To date, all digital video teleconferencing systems employ point to point communications even though some of the networks are able to switch locations. No interactive multipoint video conference systems have been implemented. The point to point communications use singularly or mixed satellite and terrestial communication links including microwave, fiber optics, and cable transmssion.

There are numerous tariffs filed for providing video teleconferencing communications. Examples of tariffs for non-synchronous and synchronous transmission have been given in this section. It has been pointed out that there are many common and resale carriers providing digital video teleconferencing communications. There is a common thread among the carriers in that they all offer a 1.544 MBS data channel.

For non-synchronous transmission such as the AT&T 1.544 MBS Tl service, there are restrictions on the codec data format or protocol which must interface with the data and communication channel. Generally, for synchronous transmission no restrictions are placed on the format of the 1.544 MBS codec data stream presented to the communications channel. It is noted, however, that the Tl format required from the codec can also be transmitted directly on a synchronous channel. Therefore, even though two physical interfaces may be required for a codec to transmit over types of channels, one data format could interface with both channels.

Finally, it is observed that all motion codecs compared in this study except one can operate at 1.544 MBS bit rate; several codecs will also operate at lower or higher rates. The predominate commonality of this communication analysis shows that the actual existing communications, FCC tariffs, required communication and data channel interfaces and motion codec transmission rates is the 1.544 MBS transmission bit rate. This 1.544 MBS rate appears to be the "standard" rate being utilized for most digital motion video teleconferencing applications.

It is believed that this transmission rate will continue to be the dominate rate for the near term. As codec compression techniques improve, the required codec transmission rate will be reduced, thereby allowing more than one codec signal to transmit simultaneously over the 1.544 MBS communication channel. This is possible now since some codecs already have optional rates at 750 KBS. It should again be noted that some applications of video teleconferencing such as command and control may require higher bit rates than 1.5 and 3.1 MBS. Bit rates ranging from 6.3 MBS to 22.0 MBS may be necessary to achieve the motion and resolution quality required for C^2 applications.

7.0 Identification and Quantification of Potential Standardization Parameters - Task 4

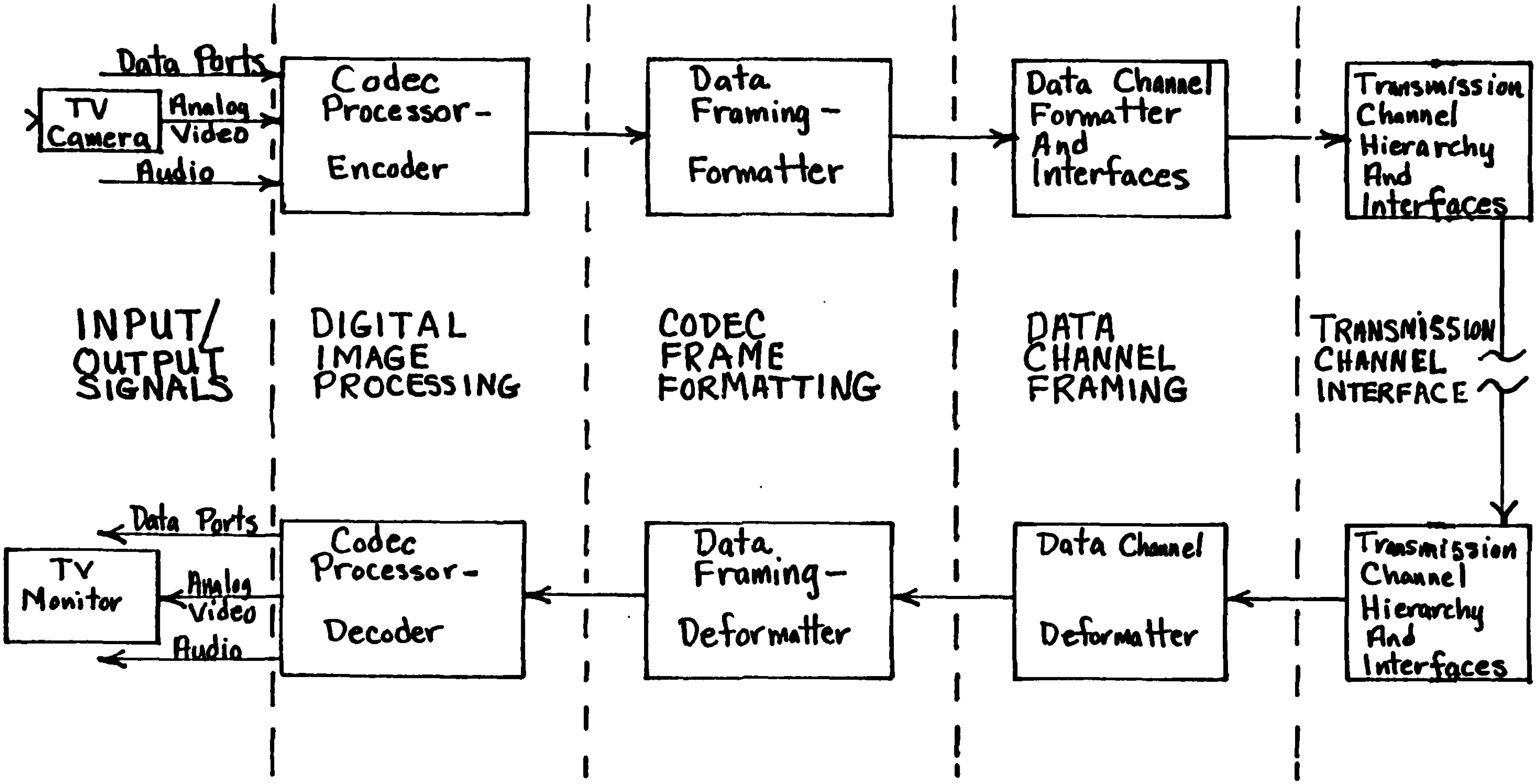
7.1 Discussion

The comparative information obtained from Tasks 1 through 3 form the basis for the identification of motion codec parameters which should be considered for potential standardization if interoperability of motion video teleconferencing systems is to be achieved among and within Federal Government agencies. It has been shown that there are several functions involving many parameters which must be standardized to achieve complete interoperability between codecs; examples are video inputs, compression algorithm processors, codec digital output formats, data channel formats, and transmission multiplex channel hierarchies. In addition to the above bit and data requirements, there are TV performance standards involving the quality of the displayed picture and motion response which should be determined for minimum acceptable performance for teleconferencing applications.

In Figure 7.1.1, a model of a functional video teleconferencing system is shown to help identify further the categories of possible standards applicable to video teleconferencing. For convenience, five groups of possible standards have been selected for purposes of discussion and identification of parameters.

1. Input and Output Signals - includes television, audio, and data.

FIGURE 7.1.1 MODEL VIDEO TELECONFERENCING SYSTEM



2. Digital Image Processing- includes color and luminance pixel and frame resolutions, compression and de-compression algorithm processing for intra and inter-frame coding, audio coding.

3. Codec Frame Format- includes basic characteristics of codec frame, bit assignments, error correction coding, encryption and decryption coding as well as multi-plexing of audio, video and data signals.

4. Data Channel Frame- includes provisions required to interface with data channels such as T1.

5. Transmission Channel Interface- includes the re-quirements to meet the hierarchy of digital data multiplex channels such as the DS1 series and bit rates.

Quite often, data channel framing and transmission channel, interfacing (4. and 5. above) are considered together and can not be separated.

7.2 Identification of Parameters

In this section parameters of the five groups defined above are further described. The major emphasis is placed upon groups 2 and 3 because they involve the codec itself.

7.2.1 Input and Output Signals

Referring to Figure 7.1.1, the first parameter grouping are the input signals to codec encoder and output signals obtained from the codec decoder. These signals are the TV video, audio, and user digital data channels. This study is primarily concerned with characteristics of the video signal.

In reviewing the codec vendor responses in Section 5, it is noticed that all codecs accept NTSC color TV signals as the video input. Thus, it seems clear that the RS170A standard for NTSC video should be specified as the standard for the input and output of video teleconferencing systems. The codec may also have capabilities to process other video standards such as RS170 or PAL signals, but it would not seem advisable at this time to also impose those standards.

The quality of the output NTSC TV signal provided by the codec decoder is of concern in video teleconferencing systems. Table 5.5.1, Section 5,contains the comparisons of the codecs for various video test signals that are commonly used in analog TV processing and transmission. These test signals do provide a measure of the overall performance of the codec and quality of the processed TV signal. SMPTE and others are performing analysis to determine theoretical limits for some of these video tests applied to digital TV codecs.

It seems reasonable that minimum performance standards should be established for codecs used in video teleconferencing. However, considerable effort needs to be expanded to determine acceptable performance criteria for these measurements.

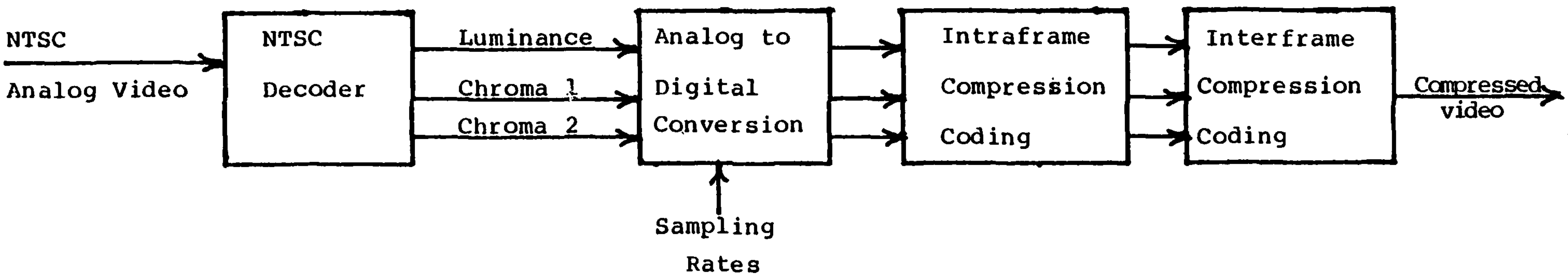
7.2.2 Digital Image Processing

The Codec Processor-Encoder in Figure 7.1.1 performs most of the functions which determine the quality of the digital television image that is ultimately transmitted to the Codec Processor-Decoder. Figure 7.2.1 contains a generalized functional block diagram of the Codec Processor-Encoder which will be discussed in the following subsections.

7.2.2.1 NTSC Decoding

Generally the first function performed, Figure 7.2.1, is to demodulate and separate the NTSC TV signal into a luminance and two chroma video signals when component coding is used instead of composite coding of the NTSC signal. (All vendors who responded to the questionnaire indicated that component coding was used.) The key parameter of interest in the component video signals is their bandwidth

Figure 7.2.1 Generalized Digital Image Processing Functions



which affects the ultimate picture resolution.

7.2.2.2 Sampling and Digitizing

The next process involves the sampling and digitizing of these component video signals which is usually performed in an analog-to-digital converter as shown in Figure 7.2.1. The important parameters associated with this function are:

1. Number of horizontal luminance and chroma pixels.
2. Number of vertical luminance and chroma pixels.
3. Encoding precision of each pixel.
4. Number of frames composed of the above horizontal and vertical which are processed per second.

Table 5.4.2 compares the values of the above parameters for the various codecs currently available commercially. A possible set of minimum values for some of these parameters, based primarily on existing equipments operating at 1.544 MBS, is contained in Table 5.4.3 and also contained in Table 7.2.1.

The number of chroma horizontal and vertical pixels was not supplied by the vendors. However, an estimate can be made by applying

Table 7.2.1 Preliminary Values of Digital Image Parameters

1. Number of horizontal luminance pixels-368 pixels minimum
2. Number of vertical luminance pixels - 480 pixels
3. Luminance encoding precision- 8 bits per pixel
4. Number of chroma component signals - 2
5. Chroma encoding precision - 6/8 bits per pixel
6. Number of frames processed - 15/30 frames per second per second (frame rate)

Note: Values of the number of chroma horizontal and vertical pixels was not supplied by the vendors. Table 7.2.2 provides estimated numbers.

the ratio of chroma to luminance sampling rates to the number of given luminance samples. These unverified estimates are listed in Table 7.2.2 in order to provide an overall view of luminance and chroma image resolution. Obviously, it is premature to suggest a set of possible values of these parameters.

7.2.2.3 Compression Algorithms

The next function generally involves the actual compressing of the digital video signals by intraframe and interframe coding techniques as shown in Figure 7.2.1. As noted previously in comparing vendor compression techniques in Section 5.7, none of the codecs commercially available are compatible or interoperable with each other. Although some vendors utilize similar conditional replenishment interframe coding and some use 2-dimensional cosine transform intraframe coding, it is quite apparent that there is considerable movement among the vendors to incorporate modifications and options to provide enhanced motion and resolution performance.

Further, there does not appear to exist any uniformally accepted or standard set of images and motion sequences which can

Table 7.2.2 Estimates of Chroma Pixels

Parameter, Specification, or Performance	Compression Labs	Nippon Electric	McMichael Ltd.	Macom DCC	ATT PMS	Widcom
1. Chroma Horizontal Sampling Rates			625 Line TV Standard			
a. Chroma 1	1.8 MHZ	1.2 MHZ	0.5MHZ-motion 3.125MHZ-graphic	CP	NR	I=1.2MHZ
b. Chroma 2	1.8 MHZ	1.2 MHZ	0.5MHZ-motion 3.125MHZ-graphic	CP	NR	Q=600KHZ
2. Estimated Chroma Horizontal Pixels		Only 1 Chroma is transmitted per line				
a. Chroma 1	92 pixels	76 pixels	32 motion 80 graphic	CP	NR	I=29 pixels
b. Chroma 2	92 pixels	76 pixels	32 motion 80 graphic	CP	NR	Q=14 pixels
3. Estimated Chroma Vertical Pixels						
a. Chroma 1	480	240	286 motion 575 graphic	CP	NR	240
b. Chroma 2	480	240	286 motion 575 graphic	CP	NR	240

be utilized to compare codec parameters for video teleconferencing systems and applications. Therefore, it is difficult at this time to specify that a particular coding technique or codec is "best" and should be adopted as a standard. Because codecs are often being upgraded by the rapidly growing compression technology and because image standards for teleconferencing need to be developed, a series of steps leading toward the development of a codec algorithm standard is presented in Section 8.0 of this report.

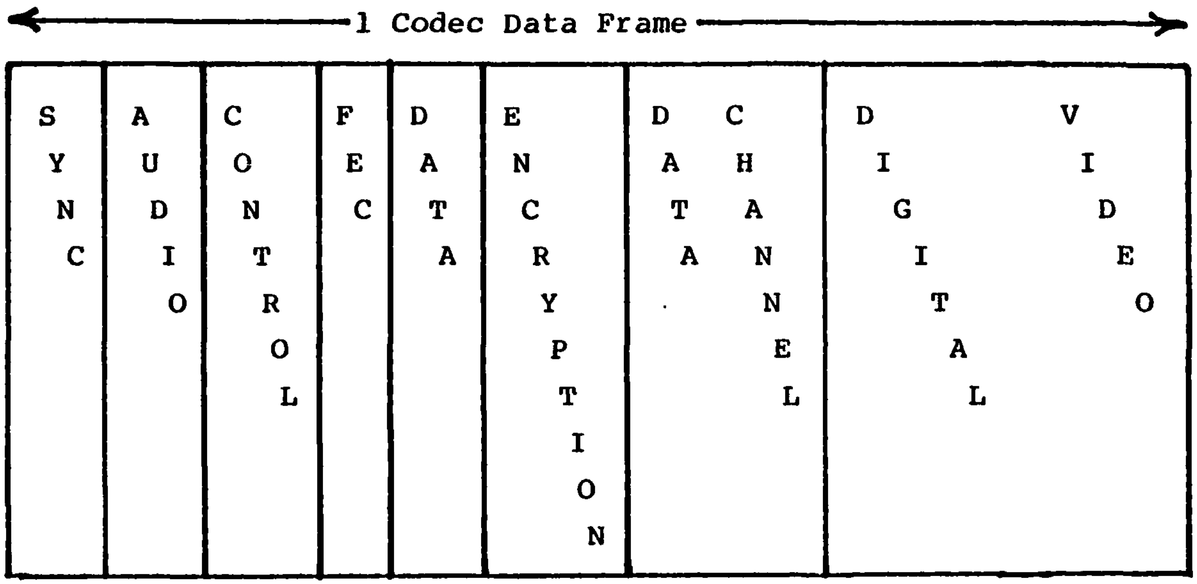
7.2.3 Codec Frame Format

Figure 7.2.2 depicts a generalized codec frame format. It shows how a codec frame could be partitioned in order to transmit information, data, and control bits as well as providing for data channel framing bits and bits for data link error correction. In determining an overall compression ratio for a codec, all bits must be used in the calculation-thus, bits other than digital video bits tend to decrease the codec compression ratio and the quality of the digital TV image at a given bit rate.

7.2.3.1 Frame Size and Bit Assignment

In Table 5.8.2, Section 5.8, the codec

Figure 7.2.2 Generalized Codec Frame Format



frame size was listed along with the number of bits assigned for the various functions performed by the codec. Two of the three respondents, NEC and MCM chose a codec frame size (193 bits per frame) which matches the primary data channel frame size used for transmitting motion video teleconferencing - 1.544 MBS T1 data channel. The advantage of this approach is to eliminate the need to provide a separate interface for T1; the disadvantage is that should another data channel be used which has a non-T1 format then a separate interface would be necessary to convert from T1.

The other codec vendor, CLI, chose a codec frame size of 4096 bits per frame. The advantages of a larger frame size are to reduce the number of housekeeping and sync bits and thus increase the number of useable video bits. As mentioned above, the disadvantage of using a non-T1 format is to require separate and/or additional bits for the T1 interface. For the CLI codec, an additional 8000 bits per second must be interspersed within the 4096 bit frame to meet T1 framing requirements. Obviously, this presents little difficulty since the CLI codec does operate on T1 data lines.

It would seem reasonable that codecs would be simpler to interoperate if a common frame format identical with the primary data channel frame format were chosen as a standard. As long as the 1.544 MBS T1 channel is used, this assumption appears valid. On the other hand, two of the codec vendors have announced product improvements which will permit the codecs to operate at bit rates considerably lower than 1.544 MBS. Thus, the T1 format may no longer be the best or preferred format.

Because technology improvements in codecs are continuing, it appears that adopting one standard frame format such as T1 may be too restrictive. This is an area which needs further study. In the meantime, it is recommended that wherever possible codec frame formats be used which are compatible with standard or commonly used channel formats at the various bit rates of concern.

7.2.3.2 Audio and Data Multiplexing

Audio and user data signals are generally included in the codec frame bit allotment- see Figure 7.2.2. They are usually multiplexed into the data frame circuits at various rates which differ for all three codecs listed in

Table 5.8.2. For interoperability requirements, the audio codecs must use compatible compression algorithms and bit rates. Similarly, input data ports to the codec must use compatible data formats and rates to achieve interoperability.

7.2.3.3 Error Correction

Forward error correction coding has been incorporated in most motion codecs to reduce the susceptibility of data link errors which allows the codecs to operate on transmission channels with BER's of about 10^{-5} or better. Additional bits must be added to the codec frame to provide the correction capability. The three codec vendoεs all use different FEC codecs to correct for different error situations. The description of error correction coding by the vendors is shown in Table 5.9.5, Section 5.9.

For interoperability of codecs, a standard FEC code must be used. Because a "standard" data frame has not been established yet, then a standard FEC can not be specified either. However, it would appear that the selection of a FEC would not be difficult to accomplish.

7.2.3.4 Encryption

An encryption function may be incorporated in a motion codec to provide information security for the users of the video teleconferencing system. Table 7.2.3 lists the encryption coding provided in the CLI, NEC, MCM codecs. Although the functional utilization may differ among the codecs, the Data Encryption Standard (DES) is used by all three vendors.

It appears that CLI and MCM use a single encryptor to code their information data bits while NEC performs separate encrypting for video and audio signals. Also, the NEC encryption function requires extra bits periodically while CLI requires no additional bits. When extra bits are required, they would be included in the codec data frame format as shown in Figure 7.2.2.

As was the case in Forward Error Correction, there appears to be general acceptance by codec vendors in using the DES algorithm for encryption of digital motion TV signals. Thus, it seems reasonable to recommend the DES algorithm as a standard.

7.2.4 Data Channel Frame

The fourth group,Figure 7.1.1,of parameters of interest in video teleconferencing systems is associated

TABLE 7.2.3 Encryption Coding

Parameter, Specification, or Performance	Compression Labs	Nippon Electric	McMichael Ltd.	Macom DCC	ATT PMS	Widcom
1. Is encryption coding provided as standard or additonal cost option?	Standard	Option	Option	CP	NR	TBD
2. Encryption algorithm	DES	DES	DES	CP	NR	TBD
3. Additional bits required	No	Yes 1 bit per 128 video bits 1 bit per 16 audio bits	NA	CP	NR	TBD
4. Other details	Encrypts video, audio, and data	Separate encryption coding used for audio and video data				

with the format and interface of the data channel used to transmit the codec data. Table 5.8.1, Section 5.8, contains the comparisons of the parameters of the transmitted data bit stream. As noted previously, all vendors transmit at 1.544 MBS rate except the WID codec. Four of the vendors provide data channel compatibility with the T1 data link and thus must meet its format requirements previously discussed in Section 5.8.

It would seem reasonable that the T1 data channel specification would be a good candidate for standardization for those codecs operating at 1.544 MBS. For other data rates, expecdially less than 1.544 MBS, the data channel frame size and format needs to be investigated. If synchronous transmission at 1.544 MBS is required, the T1 format may still be a good candidate since at least 2 codec vendors have also adopted the T1 format for the codec framing format.

7.2.5 Transmission Channel Interface

The last group of parameters in the model video teleconferencing system, Figure 7.1.1, are concerned with the transmission channel hierarchy and its interfaces. As previously discussed, the parameters associated with the transmission channel may be identical or an integral part of the data channel format parameters.

Referring to Table 5.8.1, Section 5.8, the codecs operating at 1.544 MBS T1 rate all conform to the DS1 transmission channel multiplex hierarchy requirements. There are many new common carrier organizations emerging lately who are offering the capability to transmit motion video teleconferences primarily at 1.544 MBS. Because these new transmission channel hierarchies and their interface requirements have not been thoroughly investigated, it is recommended in Section 8 of this report that a study be conducted to evaluate their characteristics as applied to motion video teleconferencing transmission.

If the number of common carriers continues to increase, it may be necessary for codec vendors to supply several different data channel and transmission channel interface standards in order to compete in the market place. Interoperability between motion codecs could probably not occur if different data and transmission channel formats are used. Therefore, in connection with the study mentioned above, aggressive coordination efforts with the common carriers should be undertaken to attempt to influence the transmission and data formats.

7.3 Candidate Parameters for Standardization

Based upon the comparisons of parameters in Section 5 and 6 and discussions contained in Sections 7.1 and 7.2, a set of candidate parameters for digital motion codecs has been identified and quantified where possible as listed in Table 7.3.1. This list of codec parameters covers the input video signals, the specification of the digitized image, the compression algorithm, codec framing format, and compatible digital interfaces for a data channel and for a transmission channel.

Standards could be proposed for adoption for some parameters immediately as little controversy or common acceptance has already been made. Some suggested parameter ranges are listed especially in the specification for the basic digitized image. However, additional effort should be expended in studies, analyses, measurements, testing, standard image and motion sequence generation and evaluations to help further establish suitable values and ranges of codec parameters for video teleconferencing. Interoperability of motion codecs can be achieved if appropriate standards are developed and adopted for the parameters contained in Table 7.3.1.

Table 7.3.1 CANDIDATE PARAMETERS FOR STANDARDIZATION

Parameter Catagory	Parameter	Recommendations		
		Suggested Standard	Suggested Parameter Range	Further Efforts/Comments
A. Input/output Signals	1. Color television signal, input and output	NTSC RS170A		All video inputs including monochrome TV, computer graphics, VTR's would be required to generate RS170A signal.
	2. Audio signal input and output characteristics			Study needed to fix audio quality requirements for motion video teleconferencing. Several standards and bit rates are in use.
	3. User data input and output ports	RS 232 RS 449		These standards are universally used and are specified by some codec vendors.
	4. Output NTSC performance measurements including video frequency reponse, signal-to-quantizing noise, luminance-chrominance gain and delay inequalities, differential gain and phase, and waveform distortions for short time line time, field time.			Standard measurement program needed to establish performance requirements for teleconferencing.

Table 7.3.1 (Continued)

Parameter Category	Parameter	Recommendations: Suggested Standard	Recommendations: Suggested Parameter Range	Recommendations: Further Efforts/Comments
B. Digital Image Processing	5. TV signal coding	Component	One luminance and two chroma video signals.	Component coding offers more flexibility in compression technology than composite coding.
	6. Horizontal luminance pixels		368 minimum	Measurements and testing with standard images and sequences are needed to evaluate further pixel and precision requirements for teleconferencing.
	7. Vertical luminance pixels		480	
	8. Luminance encoding precision		8 bits per pixel	
	9. Horizontal chroma pixels		75 minimum	
	10. Vertical chroma pixels		240-480	
	11. Chroma encoding precision		6-8 bits per pixel	
	12. Frame rate		15-30 frames/sec	
	13. Compression algorithm parameters including motion response, resolution, color fidelity, geometric distortions, artifacts.			Performance measurements and subjective testing using standard images and motion sequences should be conducted on competing codecs at various bit rates.

Table 7.3.1 (Continued)

Parameter Category	Parameter	Recommendations		
		Suggested Standard	Suggested Parameter Range	Further Efforts/Comments
C. Codec Frame Format	14. Frame size and bit assignment		T1 Format for 1.544 MBS	T1 is an excellent candidate for consideration because of the availability of data links. Other formats should be evaluated for synchronous transmission, other bit rates, and other common carriers.
	15. Audio and data coding parameters including sampling rate, precision, compression algorithm, bit rate.			Existing codecs use different coding techniques and bit rates. Measurements and subjective testing should be conducted to determine teleconferencing requirements.
	16. Error correction coding parameters including code type, block size, correction bits.			Three existing codecs use different FEC coding parameters. Study and analysis of requirements for teleconferencing need to be conducted. Susceptibility of codec compression algorithm to bit errors and expected BER of communication channels should be considered.
	17. Encryption coding parameters including block size, sync and frame bit in the clear, separate coding for information bits	DES		Three existing codecs all use the DES encryption algorithm. A study is needed to determine if all bits should be encrypted (may cause interface problems with data channel format requirements), only information bits, size of encryption block and separate coding of video and audio.

Table 7.3.1 (Continued)

Parameter Category	Parameter	Recommendations		
		Suggested Standard	Suggested Parameter Range	Further Efforts/Comments
D. Data Channel Frame	18. Bit Rate	1.544 MBS	448 KBS-2.048 MBS	Five codec vendors provide 1.544 MBS transmission. Two vendors will soon offer optional rates.
	19. Frame Format			
	* Asynchronous 1.544MBS	T1		Four Vendors currently meet T1.
	* Synchronous 1.544 MBS	RS499/ RS422		Two vendors currently meet RS 449/RS422.
	* Other Bit Rates			Study and analysis needed of new common carrier data channel requirements being used for video teleconferencing.
E. Transmission Channel Interface	20. Bit Rate/Mux Hierarchy			
	* 1.544 MBS	DS1		Four codec vendors provide this interface.
	* Other Bit Rates and other hierarchies			Study and analysis needed of new common carriers and their digital hierarchies to determine interface requirements.

7.4 Currently Adopted/Proposed DTV Standards

Little or no formal standards are known to have been adopted by CCITT, SMPTE, or EIA expressively for application to video teleconferencing codecs and systems,especially for those operating at bit rates from 500 KBS to 3.0 MBS. These highly compressed digital TV signals generally exhibit performance which is degraded somewhat from the professional quality achieved at much higher bit rates such as 45 MBS. Thus, the efforts presented in this report and those proposed in Section 8.0 are among the initial attempts to establish standards for teleconferencing systems. Some of the on-going efforts to establish DTV standards for other applications are presented below.

7.4.1 CCIR

CCIR has developed a draft recommendation, CCIR Document 11/5031E, entitled "Encoding Parameters of Digital Television for Studios". A key feature of the proposed standard is that it is equally applicable to 625 line and 525 line TV systems. By using component coding, the same number of horizontal pixels are used in both TV systems. The standard is known as the"4.2.2 Member of the Family". Table 7.4.1 contains the proposed encoding parameter values for this stnadard. Recommendation AA-11 covering the above standards has recently been finalized by CCIR.

Table 7.4.1 PROPOSED ENCODING PARAMETER VALUES FOR THE 4:2:2 MEMBER OF THE FAMILY

PARAMETERS[1]	525 line, 60 field per second systems	625-line, 50 field per second systems
1. Coded Signals	Y, R-Y, B-Y	
2. Number of samples per total line:		
• Luminance (Y)	858	864
•Color-difference (R-Y,B-Y)	429	432
3. Sampling Structure	Orthogonal, line, field and picture repetitiv R-Y and B-Y samples co-sited with odd (first, third, fifth, etc.) Y samples in each line.	
4. Sampling Frequency:		
•Luminance	13.5MHz	
•Color difference	6.75MHz	
5. Form of Coding	Uniformly quantized PCM, eight bits per sampl for the luminance signal and each color-difference signal.	
6. Number of samples per digital active line:		
•Luminance	720	
•Color difference	360	
7. Correspondence between video signal levels and quantization levels:		
•Luminance	220 quantization levels with the black level corresponding to level 16 and the peak white level corresponding to level 235.	
•Color difference	224 quantization levels in the center part of the quantization scale with zero signal corresponding to level 128.	

1. Signal parameters are identical between 525- and 625-line systems except for total samples per line.

7.4.2 SMPTE

SMPTE has an active working group on Digital Video Standards for studio applications. SMPTE has endorsed the CCIR recommendation AA-11 mentioned above. The SMPTE working group is engaged in studies to define a practical implementaiton of a studio-level interface based upon the principles of the standard for 525-line applications.

SMPTE also has a study group working on digital television transmission techniques at bit rates less than 45 MBS. As of this date no firm proposals have been forwarded for consideration by SMPTE.

7.4.3 CCITT

As mentioned previously in Section 5.8, British Telecom has submitted draft proposals to the CCITT describing a codec processing standard, Contribution 134, and a data frame format standard, Contribution 123. BT is attempting to have the CCITT adopt these standards as international standards for video teleconferencing systems. These submissions are contained in Appendix D.

8.0 Recommended Efforts Toward Proposing Codec Standards

8.1 Discussion

Several recommendations are presented in this section for studies and tests leading toward the development and proposal of standards for the parameters and specifications of digital motion video teleconferencing systems for Federal government agencies in order to provide interoperability. Within this Final Report, recommendations have been listed based upon comparisons of various codec parameters currently in existance. These recommendations are included within the efforts proposed herein. One of the most important aspects of the continuing motion codec study efforts is the coordination with organizations who are working on standards for digital television systems, equipments and transmission including SMPTE and CCITT.

8.2 Development of Standard Video Materials

Many different types of codecs have been developed and installed in various motion teleconferencing systems as described in Section 4. Vendor claims of performance are often clouded with special conditions and are based on TV images which are not typical of conferencing and do not necessarily realistically test the quality of the codec. Thus, there is a need to develop a set of standard single-frame TV pictures and sequences of TV frames for objective and comparative evaluation of both motion and freeze-frame codecs.

In the development of the single-frame pictures for testing codecs the following efforts are necessary:

a. Selection of test images.

b. Specifying the digital coding standard for converting to digital format.

c. Selecting the digital recording medium.

d. Preparing the standard master digital tape.

In generating the sequences of motion TV scenes for evaluating motion codecs, the above steps are also necessary. Additionally, the sequences should be selected which represent video teleconferencing applications envisioned by Federal government agencies.

The following questions need to be addressed:

a. Amount of motion to be changed from frame to frame.

b. Type of motion to be tested and methods for generating and quantitatively measuring the amount of motion.

c. Resolution requirements of static parts and moving parts of image.

d. Methods for generating the standard tape and how to provide test tapes for users.

e. Procedures for evaluating the tapes which have been processed by the motion codecs.

8.3 Continuing Motion Codec Study and Analysis

This Final Report describes the initial work of obtaining motion codec information and making comparisons of various parameters and characteristics. It has been mentioned several times that the digital television compression technology is progressing very rapidly in that codecs have been developed and fielded by companies in the United States, Japan, and Great Britain. Further, all three companies have planned enhancements and modifications to their codecs to improve performance or reduce costs. At least one other company is under government contract to develop a multi-bit rate motion codec for video teleconferencing. It is thus recommended that the initial study effort be continued and expanded as described below in order to continue the development of recommendations for standard parameters and characteristics.

8.3.1 Update Codec Comparisons

The information on motion codecs should be updated and expanded to include new characteristics and enhancements. A revised questionnaire should be prepared and sent to codec manufacturers. Subjective comparative evaluations of installed systems and their user applications should continue.

8.3.2 Investigate Common and Resale Carriers

The previous study of common carriers should be expanded to include a detailed questionnaire about video teleconferencing links. There are several new resale common carriers emerging and offering digital video teleconferencing communication links and networks. Among the information to be determined is the following:

a. Digital hierarchy

b. Interface requirements

c. Framing formats

d. Costs and availability

e. Bit error rates

f. Multiple nodes and networking for teleconferencing and control.

g. Switched and dedicated links and control.

8.3.3 Investigate Peripheral Equipments and Inputs/Outputs to the Codec

It was determined during this current study that the codec vendors are offering several optional capabilities to the codecs. These include audio coding, several data transmission options, still frame and high resolution graphics tranmission over the motion codec data link. It is expected that the types and number of these options will increase in the enhanced and improved codecs.

It is recommended that a detailed study be initiated to concentrate specifically on this aspect of codecs and the following information should be determined:

a. Description of user data inputs permitted including data rates, interfaces, number of ports and operational restrictions.

b. Impact upon codec motion TV performance when data ports are used.

c. Impact upon codec motion TV performance when high data rate inputs such as still frame TV graphics and facsimile graphics are transmitted over the motion codec transmission channel.

d. Description and performance of audio channels including algorithm, bit rate, and audio testing measurements.

8.3.4 Coordination with Standards Organizations

This Final Report has briefly mentioned the efforts by organizations such as CCITT, CCIR, and SMPTE which have active study and working groups studying and developing recommendations for various standards and characteristics of digital television equipments and transmission systems. Other organizations also involved in digital TV standards include IEEE and EIA in the United States. Outside the United States are the following organizations involved in digital TV:

EBU-European Broadcasing Union

ITEJ-Institute of Television Engineers of Japan

IEC-International Electrotechnical Commission

ISO-International Organization for Standardization

Because of the rapid development of digital TV equipments, codecs, and digital transmission data channels and hierarchies, it is recommended that active coordination be maintained or established with those standards organizations who are working toward national and international standards for digital video teleconferencing. This participation should expedite the timely disemination of proposed standards which could bear upon the effort to establish US Federal Standards for digital video teleconferencing.

8.4 Development of Standard Measurement Techniques for Codec Parameters

During the comparison of motion codecs in Section 5.0 of this report, it was very apparent that the different manufacturers of the codecs use different techniques and procedures for measuring the many codec parameters and characteristics. There are established procedures for measuring some of the analog TV performance tests using standard video test signals.

However, there are many characteristics of codecs for which no standard techniques or measurement criteria appear to exist. Therefore, it is recommended that a study be initiated to undertake the establishment of standard techniques and procedures for testing and evaluating motion codecs. Among the parameters, specifications, and characteristics to be measured or tested are those relating especially with motion performance of the codecs including motion response, resolution, geometric distortion, color fidelity, artifacts, frame rate, etc.

8.5 Development of Criteria For Acceptable Motion Quality

One aspect of this study has shown that no standard or criteria apparently exists for defining the acceptability of motion quality in motion codecs used in video teleconferencing systems. Further, it appears that there may be different criteria and different degrees of acceptability depending on the use or application of the system. Therefore, it is recommended that a study be instituted to examine the motion requirements of Federal government users and applications. The purpose of the study should be to establish the minimum acceptable motion criteria for various applications and to provide guidelines for the selection of codecs and transmission bit rates.

8.6 Perform Codec Testing and Evaluation

A most important recommendation in determining the comparative evaluation of motion codecs should be independent testing of the codecs to verify performance. In this way, recommendations for codec parameters, specifications, and characteristics can be evaluated and assessed as candidates for standardization.

The comprehensive testing using standard video materials (Section 8.2), applying standard measurement techniques (Section 8.4), and acceptable motion criteria (Section 8.3) should provide solid performance for the development process of recommendations for standardizing codec parameters.

8.7 Draft Recommendation for Motion Codec Standard

It is recommended that the results of all the other efforts outlined in Sec   8 be used to prepare inputs in conjunction with other cooperating United States organizations for a recommended Federal Standard for motion codecs. After adoption, motion codecs and systems built and tested to the standard could be utilized by various government agencies and be assured of compatibility and interoperability.

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